HQ Air Force Center for Environmental Excellence

MODEL
FIELD SAMPLING PLAN

Final Draft Version 1.2

September 2002

INSTRUCTIONS FOR USE OF MODEL FIELD SAMPLING PLAN

This document, *Air Force Center for Environmental Excellence Model Field Sampling Plan (FSP)*, is a template. The Model FSP identifies the minimum field sampling and quality assurance/quality control requirements. Sections of this Model FSP contain boxed instructions, *in italicized text*, which directs the Installation Restoration Program (IRP) contractor to fill in the site-specific information. *The contractor must use an italicized font for all contractor input to all draft FSPs*; however, non-italicized text shall be used in the final version of the FSP. The Model FSP is furnished to the contractors in an electronic format. The contractors are required to follow the boxed instructions for each section and include site-specific information. Once this information has been completed, the boxed instructions shall be deleted. In this Model FSP, all page numbers in the table of contents, list of figures, list of tables, and some sections of the report are presented as boxed instructions. The contractor must insert the correct page numbers in its final version. All standard text and tables (not the boxed instructions) in the Model FSP shall remain as provided in the final site-specific FSP. Portions of sections five and six may be deleted if the project will not include that particular activity (e.g., if ground penetrating radar is not required for the project, Section 5.3.2.1 may be deleted). By definition, the final FSP and the AFCEE Quality Assurance Project Plan (QAPP) shall constitute an AFCEE Sampling and Analysis Plan (SAP).

All subcontractors performing work in support of AFCEE IRP contracts shall perform their services in accordance with the requirements specified in their AFCEE contract, corresponding statement of work (SOW), the AFCEE QAPP and this model FSP. Any exception to or deviation from these requirements must be noted in Appendix A of the draft and final FSP. Each exception or deviation from these requirements shall be identified by document, chapter, subtitle, paragraph, page, and line with supporting justification for the change. Written authorization of the AFCEE contracting officer must be obtained and included in Appendix A for any proposed exception to or deviation from these requirements. No project work shall be performed until the written authorization has been obtained. As specified in current AFCEE contracts, **these AFCEE Model FSP requirements supersede field-sampling requirements specified in all AFCEE Handbooks to Support Remedial Investigation/ Feasibility Study Statements of Work.** The requirements specified in this document were developed in order to assure comparability across AFCEE IRP contractors and subcontractors who perform field sampling and investigative services.

Do not include this page in the final version of the FSP.

Provide a title page in the following format:

Installation Shield or Logo

FINAL -or- DRAFT

FIELD SAMPLING PLAN

Prepared for:

Name the work effort (e.g., OU2 Site Characterization)
Name the Air Force Installation

Prepared by:

Name of contractor
Address of contractor

Contract No.
Delivery Order No.

revision, month, year

PREFACE

The prime contractor shall briefly describe the nature of the work covered in the Field Sampling Plan (FSP), the organization, people involved, and the time period for the FSP. It shall include: (1) purpose and contracting information on FSP, (2) professional responsibilities and roles (contractor personnel), (3) acknowledgments, (4) the period of work, (5) the Contracting Officer's Representative (COR), and (6) the Team Chief (if different than the COR).

LIST OF ACRONYMS AND ABBREVIATIONS

AA	atomic absorption
AFCEE	Air Force Center for Environmental Excellence
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
bgs	below ground surface
Br^-	bromide
°C	degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulation
Cl^-	chloride
cm/sec	centimeters per second
COC	chain of custody
COR	contracting officer's representative
DEQPPM	Defense Environmental Quality Program Policy Memorandum
DO	dissolved oxygen
DOD	Department of Defense
DOT	Department of Transportation
DNAPL	dense non-aqueous phase liquid
DQO	data quality objective
EC	electrical conductivity
EDB	ethylene dibromide
EPA	(US) Environmental Protection Agency
ERPIMS	Environmental Resources Program Information Management System
F^-	fluoride
FID	flame ionization detector
FSP	Field Sampling Plan
ft	foot or feet

g/cm^3	grams per cubic centimeter
G	glass
gal/ft^3	gallons per cubic foot
GPR	ground penetrating radar
H_2SO_4	sulfuric acid
HCl	hydrochloric acid
HNO_3	nitric acid
HSP	Health and Safety Plan
IAW	in accordance with
IRP	Installation Restoration Program
lbs/gal	pounds per gallon
LNAPL	light non-aqueous phase liquid
mL	milliliter
mL/L	milliliters per liter
MS/MSD	matrix spike/matrix spike duplicate
$Na_2S_2O_3$	sodium thiosulfate
NCP	National Contingency Plan
NO_2^-	nitrite
NO_3^-	nitrate
NTU	nephelometric turbidity unit
OD	outside diameter
OSHA	Occupational Safety and Health Administration
OVA	organic vapor analyzer
P	polyethylene
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PID	photoionization detector
PO_4^{-3}	phosphate
PPE	personal protective equipment
PVC	polyvinyl chloride

QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RI/FS	remedial investigation/feasibility study
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SCAPS	Site Characterization and Analysis Penetrometer System
SO_4^{-2}	sulfate
SOW	statement of work
SP	spontaneous potential
SVOC	semivolatile organic compound
T	California brass
TCLP	toxicity characteristic leaching procedure
TPH	total petroleum hydrocarbon
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VOC	volatile organic compound
WP	work plan
m**m**	micrometer
3-D	three-dimensional

Add other acronyms and abbreviations used.

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1.0 INTRODUCTION

The Field Sampling Plan (FSP) presents, in specific terms, the requirements and procedures for conducting field operations and investigations. This project specific FSP has been prepared to ensure (1) the data quality objectives specified for this project are met, (2) the field sampling protocols are documented and reviewed in a consistent manner, and (3) the data collected are scientifically valid and defensible. This site specific FSP and the Air Force Center for Environmental Excellence (AFCEE) Quality Assurance Project Plan (QAPP), shall constitute, by definition, an AFCEE Sampling and Analysis Plan (SAP).

The National Contingency Plan (NCP) specifies circumstances under which a FSP is necessary for Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) response actions. For cleanup actions at the remedial investigation/feasibility study (RI/FS) stage, the NCP requires lead agencies to develop sampling and analysis plans which provide a process for obtaining data of sufficient quality and quantity to satisfy data needs. Such sampling and analysis plans must include a field sampling plan. 40 CFR 300.430 (b)(8)(ii).

Guidelines followed in the preparation of this plan are set out in the: *Data Quality Objectives Process for Superfund, Interim Final Guidance* (U.S. Environmental Protection Agency [EPA], 1993).

The prime contractor shall include here any additional reference documents used in the preparation of this FSP.

This FSP is required reading for all staff participating in the work effort. The FSP shall be in the possession of the field teams collecting the samples. All contractors and subcontractors shall be required to comply with the procedures documented in this FSP in order to maintain comparability and representativeness of the collected and generated data.

Controlled distribution of the FSP shall be implemented by the prime contractor to ensure the current approved version is being used. A sequential numbering system shall be used to identify controlled copies of the FSP. Controlled copies shall be provided to applicable Air Force managers, regulatory agencies, remedial project managers, project managers, and quality assurance (QA) coordinators. Whenever Air Force revisions are made or addenda added to the FSP, a document control system shall be put into place to assure (1) all parties holding a controlled copy of the FSP shall receive the revisions/addenda and (2) outdated material is removed from circulation. The document control system does not preclude making and using copies of the FSP; however, the holders of controlled copies are responsible for distributing additional material to update any copies within their organizations. The distribution list for controlled copies shall be maintained by the prime contractor.

2.0 PROJECT BACKGROUND

2.1 THE U.S. AIR FORCE INSTALLATION RESTORATION PROGRAM

The objective of the U.S. Air Force Installation Restoration Project (IRP) is to assess past hazardous waste disposal and spill sites at U.S. Air Force installations and to develop remedial actions consistent with the NCP for sites that pose a threat to human health and welfare or the environment. This section presents information on the program origins, objectives, and organization.

The 1976 Resource Conservation Recovery Act (RCRA) is one of the primary federal laws governing the disposal of hazardous wastes. Sections 6001 and 6003 of RCRA require federal agencies to comply with local and state environmental regulations and provide information to the EPA concerning past disposal practices at federal sites. RCRA Section 3012 requires state agencies to inventory past hazardous waste disposal sites and provide information to the EPA concerning those sites.

In 1980, Congress enacted CERCLA (Superfund). CERCLA outlines the responsibility for identifying and remediating contaminated sites in the United States and its possessions. The CERCLA legislation identifies the EPA as the primary policy and enforcement agency regarding contaminated sites.

The 1986 Superfund Amendments and Reauthorization Act (SARA) extends the requirements of CERCLA and modifies CERCLA with respect to goals for remediation and the steps that lead to the selection of a remedial process. Under SARA, technologies that provide permanent removal or destruction of a contaminant are preferable to action that only contains or isolates the contaminant. SARA also provides for greater interaction with public and state agencies and extends the EPA's role in evaluating health risks associated with contamination. Under SARA, early determination of Applicable or Relevant and Appropriate Requirements (ARARs) is required, and the consideration of potential remediation alternatives is recommended at the initiation of an RI/FS. SARA is the primary legislation governing remedial action at past hazardous waste disposal sites.

Executive Order 12580, adopted in 1987, gave various federal agencies, including the Department of Defense (DOD), the responsibility to act as lead agencies for conducting investigations and implementing remediation efforts when they are the sole or co-contributor to contamination on or off their properties.

To ensure compliance with CERCLA, its regulations, and Executive Order 12580, the DOD developed the IRP, under the Defense Environmental Restoration Program, to identify potentially contaminated sites, investigate these sites, and evaluate and select remedial actions for potentially contaminated facilities. The DOD issued the Defense Environmental Quality Program Policy Memorandum (DEQPPM) 80-6 regarding the IRP program in June 1980, and implemented the policies outlined in this memorandum in December 1980. The NCP was issued by EPA in 1980 to provide guidance on a process by which: (1) contaminant release could be reported, (2) contamination could be identified and quantified, and (3) remedial actions could be selected. The NCP describes the responsibility of federal and state governments and those responsible for contaminant releases.

The DOD formally revised and expanded the existing IRP directives and amplified all previous directives and memoranda concerning the IRP through DEQPPM 81-5, dated 11 December 1981. The memorandum was implemented by a U.S. Air Force message dated 21 January 1982.

The IRP is the DOD's primary mechanism for response actions on U.S. Air Force installations affected by the provisions of SARA. In November 1986, in response to SARA and other EPA interim guidance, the U.S. Air Force modified the IRP to provide for an RI/FS program. The IRP was modified so that RI/FS studies could be conducted as parallel activities rather than serial activities. The program now includes ARAR determinations, identification and screening of remedial technologies, and development of alternatives. The IRP may include multiple field activities and pilot studies prior to a detailed final analysis of alternatives. Over the years, requirements of the IRP have been developed and modified to ensure that DOD compliance with federal laws, such as RCRA, NCP, CERCLA, and SARA, can be met.

2.2 PROJECT PURPOSE AND SCOPE

The prime contractor shall briefly describe and discuss the site-specific FSP purpose, scope, use, and the FSP's compliance with the corresponding SOW.

2.3 PROJECT SITE DESCRIPTION

The prime contractor shall: (1) identify the Air Force Base or facility, (2) identify, in a figure, the locations of all IRP sites, and (3) describe each site's location, characteristics, and history.

2.4 PROJECT SITE CONTAMINATION HISTORY

The prime contractor shall: (1) summarize the contamination history of each site, and (2) discuss the findings from previous IRP investigations and their significance.

3.0 PROJECT SCOPE AND OBJECTIVES

3.1 DATA QUALITY OBJECTIVES (DQOs)

The prime contractor shall: (1) discuss the data quality objectives (DQOs) for this project, (2) discuss how project specific decision rules were derived from the DQO process, (3) summarize the objectives for each site, (4) justify the number of samples, location of samples, types of samples, and types of analytical analyses, and field activities needed, (5) discuss the data quality categories, e.g., screening data vs. definitive data, needed for the project, (6) reference the AFCEE Quality Assurance Project Plan (QAPP) will be used to generate the data as well as define the laboratory quality assurance measures, (7) describe the intended use of the data acquired, and (8) reference, on site maps, all the intended field activities.

The prime contractor shall: (1) use the data quality objective process for justifying the scope of work at each site, and (2) reference and integrate the data quality objective process as stated in the Work Plan (WP) for this project

3.2 SAMPLE ANALYSIS SUMMARY

The prime contractor shall, for each analytical method, on a site-by-site and a project-total basis list: (1) the number of analyses, by site and total, (2) the total number of environmental samples for all matrices, (3) the number of trip blanks, (4) the number of ambient condition blanks, (5) the number of equipment blanks, and (6) the number of field duplicate samples, (7) the number of screening samples (if screening samples are taken) to be confirmed and, (8) identify any deviations from the sampling activities specified in the SOW. The sample analysis summary form that shall be used is shown in Table 3-1.

3.3 FIELD ACTIVITIES

The prime contractor shall summarize, in tabular form as shown in Table 3-2, the type and number of field activities to be conducted at each site. Identify the number of monitor wells to be constructed, the type and number of aquifer tests, frequency of sampling, etc. Also, show on site maps all planned field activities.

Table 3-1
Sample Analysis Summary

Site	Method	Matrix	# Samples	# Equipment Blanks	# Ambient Blanks	# Trip Blanks	# Field Duplicates	Total # Samples

Table 3-2
Field Activities Summary

Site	Activity	#

4.0 PROJECT ORGANIZATION AND RESPONSIBILITY

The prime contractor shall: (1) describe the project organization and key personnel responsibilities (including who is responsible for data assessment and performance of audits of laboratory and field activities), (2) provide a project organizational chart identifying task managers and individuals responsible for performance of the project, (3) provide a list of names of all key participants, including organization names and telephone numbers for project, field, and laboratory QA officers, (4) provide a description of the authority given to each key participant with an emphasis on the authority of the key individuals to initiate and approve corrective actions and, (5) describe the role of regulatory representatives.

4.1 SUBCONTRACTORS

The prime contractor shall: (1) identify all contractors and subcontractors, including fixed-base analytical laboratories, mobile analytical laboratories, and well drillers, (2) describe the subcontractors' scope and their performance in the project, and (3) identify all proposed subcontractors that may provide backup services for the project.

The prime contractor shall provide an organizational chart, a list of key personnel, and a descriptive text, as stated in the previous section, for all subcontractors identified.

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5.0 FIELD OPERATIONS

The prime contractor shall provide detailed descriptions and applicable specifications for conducting any additional field operations that have not already been described. The specific field operations for this project shall be summarized in Section 3.0, and the locations of all proposed field operations shall be shown on site maps in Section 3.0.

5.1 GEOLOGIC STANDARDS

The lithologic descriptions for consolidated materials (igneous, metamorphic, and sedimentary rocks) shall follow the standard professional nomenclature (cf. Tennissen, A.C., 1983, *Nature of Earth Materials*, 2nd Edition, p. 204-348), with special attention given to describing fractures, vugs, solution cavities and their fillings or coatings, and any other characteristics affecting permeability. Colors shall be designated by the Munsell Color System.

The lithologic descriptions for unconsolidated materials (soils [engineering usage] or deposits) shall use the name of the predominant particle size (e.g., silt, fine sand). The dimensions of the predominant and secondary sizes shall be recorded using the metric system. The grain size and name of the deposit shall be accompanied by the predominant mineral content, accessory minerals, color, particle angularity, and any other characteristics. The clastic deposit descriptions shall include, as a supplement, symbols of the Unified Soil Classification System. The color descriptions shall be designated by the Munsell Color System.

The sedimentary, igneous, and metamorphic rocks and deposits shall be represented graphically by the patterns shown in Figure 5-1. Columnar sections, well and boring logs, well construction diagrams, cross sections, and three-dimensional (3-D) diagrams shall use these patterns. Supplementary patterns shall follow Swanson, R. G., 1981, *Sample Examination Manual*, American Association of Petroleum Geologists, p. IV-41 and 43. Geologic structure symbols shall follow *American Geological Institute Data Sheets*, 3d Edition, 1989, sheets 3.1 through 3.8.

Figure 5-1
Lithologic Patterns for Illustration

Sediments and Sedimentary Rocks

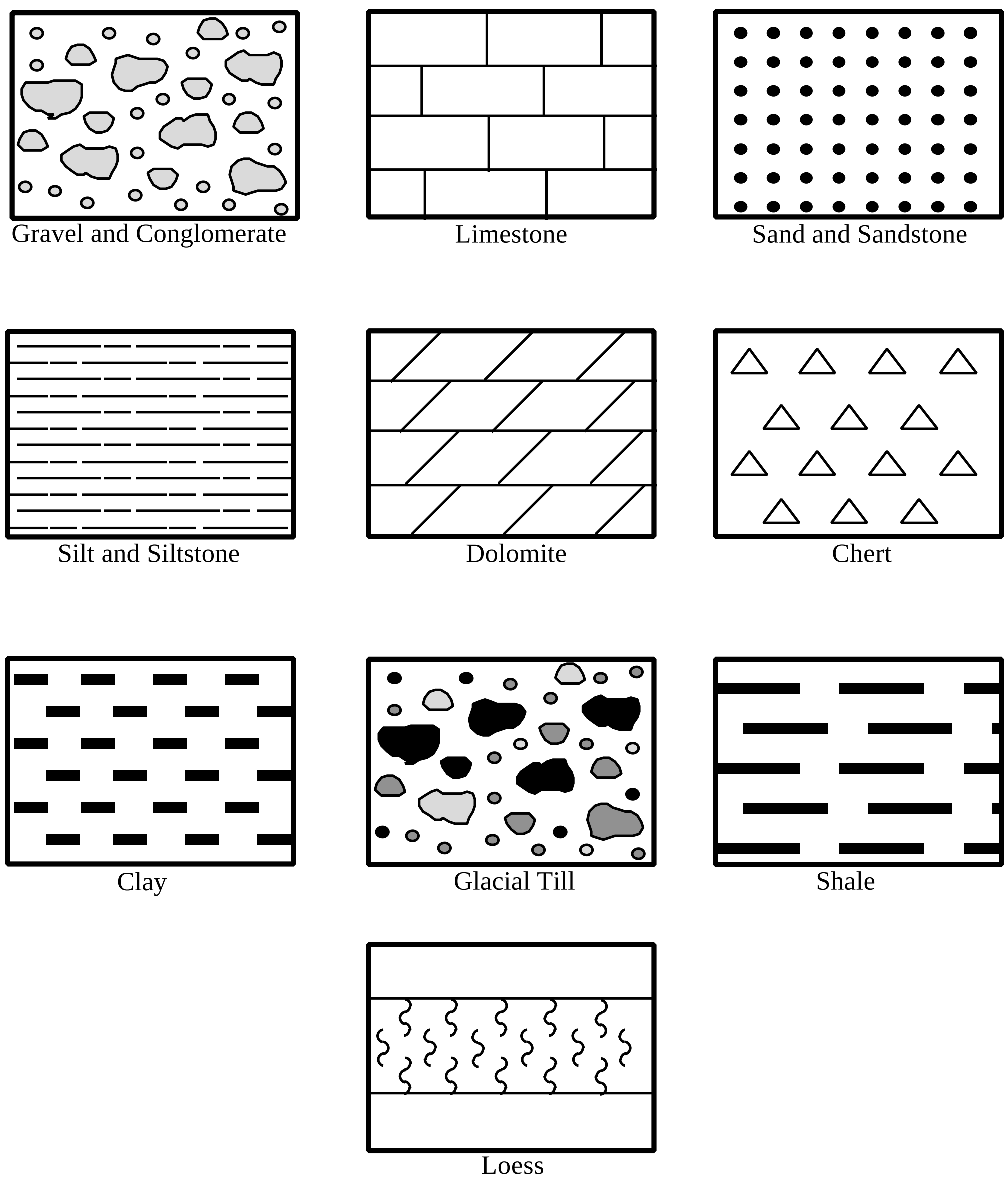
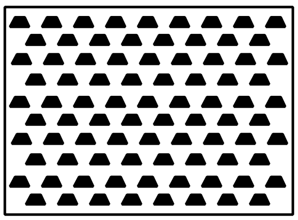
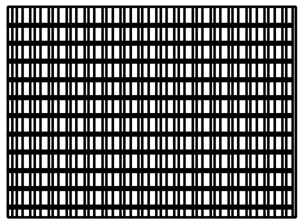


Figure 5-1
Lithologic Patterns for Illustration

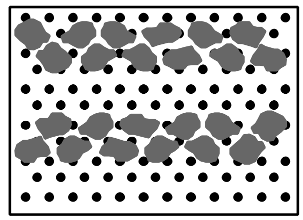
Igneous Rocks



Undifferentiated Intrusive

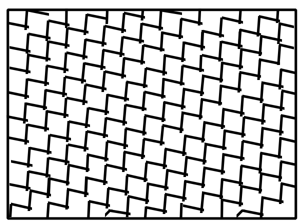


Basalt



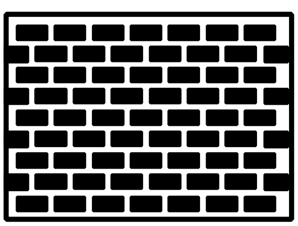
Volcanic Breccia and Tuff

Metamorphic Rocks

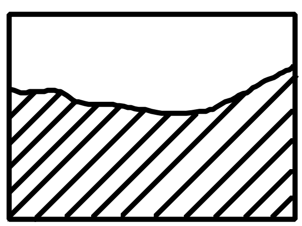


Undifferentiated

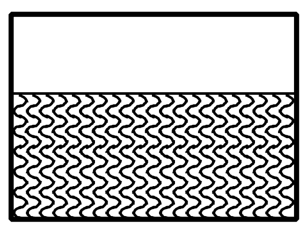
Miscellaneous



Fill



Undifferentiated Bedrock



Residium

The scales for maps, cross sections, or 3-D diagrams shall be selected in accordance with the geologic and hydrologic complexity of the area and the purposes of the illustrations. Geophysical logs shall be run at a constant vertical scale of 1 inch equals 20 feet. When geophysical logs are superimposed on geologic logs, cross sections, or 3-D diagrams, the scales shall be the same. If defining geological conditions requires other scales, additional logs at those scales shall be provided.

For orientation, the cross sections shall show the Northern end on the viewer's right. If the line of cross section is predominantly East-West, the Eastern end is on the right. Maps shall be oriented with North toward the top, unless the shape of the area dictates otherwise. Indicate orientation with a North arrow.

5.2 SITE RECONNAISSANCE, PREPARATION, AND RESTORATION PROCEDURES

The prime contractor shall describe, in addition to what is already described in this section, any special site preparation requirements (e.g., fencing off the site to prevent access by unauthorized personnel, heavy equipment to clear trees, any permits needed prior to the start of intrusive activities on the site, possibility of encountering unexploded ordnance). Provide information on the field office/laboratory locations and the location of emergency equipment (e.g., fire extinguishers and personnel safety equipment). Describe how the site will be restored after field activities have been completed.

Areas designated for intrusive sampling shall be surveyed for the presence of underground utilities. Utility locations are determined using existing utility maps, and in the field, are verified using a hand-held magnetometer or utility probe. Vehicle access routes to sampling locations shall be determined prior to any field activity.

A centralized decontamination area shall be provided for drilling rigs and equipment. The decontamination area shall be large enough to allow storage of cleaned equipment and materials prior to use, as well as to stage drums of decontamination waste. The decontamination area shall be lined with a heavy gauge plastic sheeting, and designed with a collection system to capture decontamination waters. Solid wastes shall be accumulated in 55-gallon drums and subsequently transported to a waste storage area designated by the Air Force (see Section 5.13). Smaller decontamination areas for personnel and portable equipment shall be provided as necessary. These locations shall include basins or tubs to capture decontamination fluids, which shall be transferred to a large accumulation tank as necessary. These designated areas of decontamination shall be designated on the site maps specified in Section 3.0.

Field office sites shall be designated and shown on the site maps specified in Section 3.3.

Each work site or sampling location shall be returned to its original condition when possible. Efforts shall be made to minimize impacts to work sites and sampling locations, particularly those in or near sensitive environments such as wetlands. Following the completion of work at a site, all drums, trash, and other waste shall be removed. Decontamination and/or purge water and soil cuttings shall be transported to the designated locations as described in Section 5.13.

5.3 GEOPHYSICAL SURVEYS

The prime contractor shall describe, in addition to what is already described in this section, the specific equipment to be used and how the survey(s) will be conducted. Include information on specific equipment calibration, establishment of grid patterns, and quality control (QC) procedures for surveys.

5.3.1 General Requirements For Geophysical Surveys

General requirements for all geophysical surveys are: (1) the prime contractor shall have a state licensed geologist or engineer to supervise AFCEE work, (2) the locations of boreholes logged with geophysical instruments shall be shown on a site map, (3) the locations of surface geophysical grid system layouts shall be shown on a site map, (4) the location of areas analyzed with subsurface geophysical techniques shall be shown on a site map (5) final results shall be presented in plan views and cross sections. Contours shall be used where appropriate, (6) the interpretation of results shall discuss positive and negative results as well as limitations of the method and data and, (7) the interpretation of the data shall be incorporated into the conceptual site model.

5.3.2 Surface Geophysical Surveys

Surface geophysical techniques include, but are not limited to, ground penetrating radar (GPR), magnetometry, and electromagnetic techniques. Use of any of these techniques is dictated by the project data quality objectives (Section 3.0), and the objectives of these techniques is to locate the boundaries of suspected or known underground metallic objects or volumes of disturbed soil. The areas to be surveyed are described and shown on site maps presented in Section 3.0.

Surface geophysical surveys are conducted within predetermined grids defined by transect lines crossing each site or area of interest. The spacing of the grids is determined from the approximate dimensions of the features to be located. Qualified individuals shall conduct the surveys and shall be supervised by a state licensed geologist or state licensed engineer.

Location and elevation information sufficient to map and assess the survey results shall be recorded. Depending on the level of accuracy and detail required, northing and easting from a surveyed reference point, measurements in a third order survey, depth below ground surface (bgs), and/or professionally surveyed points and transects may be included. Location data, instrument numbers, calibration information, geophysical interpretation, and maps for all geophysical surveys shall be stored in project files.

General requirements for surface geophysical surveys are: (1) the prime contractor shall correlate surface survey data (profiles and soundings) with at least one soil boring, well bore, or outcrop at the same site as the survey and, (2) the location and elevation of at least two points of the geophysical survey grid shall be surveyed according to the specifications of Section 5.11

5.3.2.1 Ground Penetrating Radar (GPR)

Ground penetrating radar is a geophysical survey technique that provides a continuous real-time measurement of subsurface layering. The instrumentation for this type of investigation consists of a radar control unit, signal processing and conditioning circuitry, and a graphical recorder. This unit is connected to a transducer by an electrical umbilical cable. The transducer (antenna) is towed along a traverse and transmits radar impulses into the ground. Interfaces between soil layers change the physical properties of the subsurface; as these are encountered, the radar impulse typically undergoes an abrupt change in velocity, causing some of the radar energy to be reflected back to the antenna. The time the radar signal takes to travel from the antenna to a reflecting soil interface and back is directly proportional to the interface depth.

Recording these depth-dependent impulses on a scanning, time-based graphic chart recorder creates a cross-section of the longitudinal distribution of subsurface layers and other features. The survey area shall be large enough to identify the natural distribution of layers.

5.3.2.2 Magnetometry

Magnetometer surveys measure variations in the earth's magnetic field. Measurements of the magnetic gradient can be used to locate buried ferrous objects such as tanks, pipelines, and metallic debris.

Magnetometer surveys are conducted using a magnetometer/gradiometer or equivalent equipment (e.g., Geometrics model 856AG® proton precession magnetometer/gradiometer). The magnetometer has two sensors and an electronics package. The magnetometer can collect both total field data and vertical gradient data and can discriminate to 0.2 gammas in a total field of 40,000 to 60,000 gammas. Magnetic readings are stored in memory with the time of day, station numbers, and line numbers of the readings. A base station for magnetic readings is established at the start of each day's measurements. Magnetic readings are collected and recorded from the base station in the morning, at noon, and at the end of day to evaluate instrument drift.

5.3.2.3 Electromagnetic Methods

An electromagnetic survey measures the electrical conductivity of a subsurface volume, which is a function of the soil or rock type, porosity/permeability, and fluid content. The measured values, referred to as terrain conductivity, are obtained without direct ground contact through electromagnetic induction. Data collected during an electromagnetic survey can be used to map the location of buried metallic objects; depth or thickness determinations cannot be made solely by this method. The electromagnetic technique can also detect chemicals or contaminant plumes (e.g., hydrocarbons in high concentrations or other conductive or resistive chemicals).

A ground conductivity meter (e.g., Geonics Ltd. EM-31DL® or EM-34) is used to obtain terrain conductivity data. The transmitting and receiving coils on this instrument are mounted at the ends of 4-foot tubes that project horizontally from either end of the instrument console. The 8-foot coil separation results in a depth of penetration of approximately 15 to 18 feet. A data logger records quadrature and in-phase data at each measuring station.

5.3.3 Borehole Geophysical Surveys

Borehole geophysical techniques employed include resistivity, spontaneous potential (SP), gamma ray, sonic, induction, neutron, down hole camera, cross-hole GPR, topography and caliper logging. Some of the theory and general procedures for borehole geophysical techniques are described in Groundwater and Wells, Fletcher G. Driscoll, 1986; others can be found in any borehole geophysical text.

Geophysical logging, such as resistivity, SP, and caliper logging, may be performed in boreholes to identify soil/lithologic types before monitor well screen intervals are selected. Gross-count natural gamma ray logging may be in cased or uncased wells to augment identification and correlation of lithologies or soil types between boreholes.

Borehole geophysical logging shall be conducted by a qualified individual and a qualified, state licensed geologist, geophysicist, or engineer shall supervise all logging activities. Downhole geophysical tools, cables, probes, and other equipment are decontaminated before and after being lowered into a borehole. For each geophysical tool, calibration data and scale parameters are verified before logging begins and are documented for each borehole. Geophysical data are stored in hard copy and electronic formats. After logging, a reproducible copy of the field strip-chart log with a heading specifying project, borehole number, location and depth, geophysical equipment types, and equipment settings shall be maintained in the project file.

General requirements for borehole geophysical surveys are: (1) all downhole equipment shall be decontaminated according to the specification of Section 5.12, (2) borehole measurements shall be recorded both going into the hole and coming out of the hole, (3) paper copies of curves generated from each logging run shall show all the curves at the scale of 1 inch equals 20 feet; and each paper log shall indicate the location of the well, date of log acquisition, type of survey instrument, and a list of other instruments used in that borehole; and interpretations shall be annotated on the margins of paper log records, (4) all logs shall be referenced to a measuring point notched in the surface casing or to ground level if the well is not cased, (5) radioactive sources or devices shall not be used unless they are explicitly called for in the statement of work (SOW) and, (6) adverse borehole conditions shall be reported in the field log.

5.3.3.1 Electric Logs

Electrical resistivity logging is conducted in conjunction with SP logging. When used together, these methods are commonly referred to as electric or "E" logs.

Resistivity and SP are simultaneously measured from the bottom of the hole upward. The measuring instruments shall be raised toward the surface at a rate no greater than 10 feet per minute. Monitor well screen depths are selected in the field based on interpretation of the strip-chart log. Equivalent measurement scales increase the accuracy of geologic interpretation in the field and, therefore, screen interval selection.

The scales selected for portraying resistivity or SP readings shall be the same at all boreholes. The appropriate scale is determined in the field by conducting offset logs prior to the final survey. Offset logs are a quality assurance and calibration step that involves logging an upper or lower portion of the borehole and adjusting the log response to obtain the optimum scale. Scales to be adjusted are the horizontal (millivolts for SP and ohm-meters for resistivity) and vertical (feet). The resistivity logs shall consist of the short-normal (16-inch) and long-normal (64-inch) configurations.

5.3.3.2 Natural Gamma Ray Logs

Natural gamma ray logging is used to estimate lithologic characteristics of geologic formations by recording gamma radiation emissions. The gamma ray logging tool contains one or more scintillation detectors which measure the natural radioactivity in soil layers adjacent to the borehole. Gamma logging may be used in conjunction with SP, resistivity, and caliper logs in fluid-filled boreholes. This technique allows logging through the casing or the well pipe after well construction; however, the radiation measurements are attenuated by well casing. Generally, this technique works very well in sand and clay formations.

The mineral distribution in subsurface layers reduces the potential for use of gamma ray logs, and the technique does not provide sufficient additional data to warrant widespread use. This technique shall therefore only be used where the mineral constituents of the geologic formations indicate the log shall provide additional interpretive information.

5.3.3.3 Caliper Logs

Caliper logs measure the variations in the borehole diameter. A caliper, a spring-loaded mechanical device with one to four adjustable arms that press against the borehole wall, measures the diameter in cased and uncased boreholes. Variations in the borehole diameter, factors such as borehole erosion (washout), the presence of swelling clays or resistant strata, and the volume of filter pack or grout needed for well completion, are determined. Caliper logs are conducted by lowering the device to the bottom of the borehole and recording the measurements as the caliper is raised.

5.3.3.4 Seismic Refraction/Reflection

Seismic refraction/reflection methods use seismic waves to determine the thickness and extent of lithologic and aquifer units. Seismic surveys are based on creating seismic waves in the subsurface by hammering, dropping a heavy object, or explosives. The seismic waves are refracted and reflected as the waves travel through the subsurface. As the waves are refracted/reflected back to the surface, geophones placed firmly in the ground detect the seismic wave. The analyses of refracted/reflected waves can determine the depth to bedrock at a potential drilling site.

5.4 SOIL GAS SURVEYS

The prime contractor shall describe, in addition to what is already described in this section, the equipment to be used, site-specific limitations of the survey method, and how the survey will be conducted. Include sample-location information on the grid pattern, and QC procedures that will be used.

The primary function of soil gas surveys is to assist in identifying potential source areas for soil and ground-water contamination. Soil gas shall also be used in small source areas to help target soil boring, monitor well, and indoor air sampling locations. Soil gas sampling networks shall be designed to obtain all necessary information with a minimal expenditure of time and resources. The development of the sampling network shall be based on background information, properties of the vadose zone, and hydrogeologic properties of the area, as discussed in Sections 2.0 and 3.0. Soil gas sampling procedures are discussed in Section 6.1.6.

Common sampling schemes include grids, transect lines, biased, random, and combinations. Grids consist of sampling points on perpendicular lines at equal distances along the lines. The size of the grid shall be dependent upon site characteristics and sampling objectives. The transect line sampling network is typically used to find a source area of contamination. Sampling points are placed along a line between the area of impact and the suspected source area. In a biased sampling network, sample points are placed near the suspected source of contamination to locate "hot spots" and further delineate the extent of contamination. This sampling network shall not be used for unknown conditions. Random sampling networks use a numbered grid system. The sample points are selected by a random number generator. This network is typically used in areas where little information is available or no contamination is suspected. Combined type of sampling network, consists of a combination of the above reference networks. The interval between sampling points shall be dependent on the objectives of the investigation.

The selection of sampling schemes shall be described and discussed in Section 3.0 of this FSP. The type(s) of sampling schemes selected shall be dependent on site conditions and the data quality objectives for the project. Soil gas sampling shall be used when ground-water sampling indicates contamination or when vadose zone contamination is suspected.

5.5 BOREHOLE DRILLING, LITHOLOGIC SAMPLING, LOGGING, AND ABANDONMENT

The prime contractor shall describe, in addition to what is already described in this section, the drilling method and equipment to be used for lithologic sampling and logging. If drilling fluid is used, provide information on its composition.

5.5.1 General Drilling Procedures

All drilling activities shall conform to state and local regulations and shall be supervised by a state licensed geologist or state licensed engineer. The contractor shall obtain and pay for all permits, applications, and other documents required by state and local authorities.

The location of all borings shall be coordinated, in writing, with the base civil engineer or equivalent before drilling commences. When drilling boreholes through more than one water-bearing zone or aquifer, the contractor shall take measures to prevent cross-connection or cross-contamination of these zones or aquifers.

The drill rig shall be cleaned and decontaminated in accordance with (IAW) the procedure in Section 5.12. The drill rig shall not leak any fluids that may enter the borehole or contaminate equipment placed in the hole. The use of rags or absorbent materials to absorb leaking fluids is unacceptable.

Drilling fluids shall consist of air, water, or mud. If air is used, it shall be filtered to remove organic vapors, and filters shall be changed daily. The effectiveness of the air filter shall be checked at least every 4 hours using a photo ionization detector (PAD) or flame ionization detector (FID). If organic vapors are detected in air passing through the downstream end of the air line or drill stem, their source (i.e., filter, contaminated line) shall be decontaminated or replaced. If water is used, the contractor shall provide chemical analyses of the water for AFCEE approval. Only water from a pre-approved source shall be used as a drilling fluid and the water quality shall be monitored daily for suspected analytes of concern. Drilling mud, if used, shall consist of 100 percent sodium bentonite and shall be approved by the AFCEE. The prime contractor shall provide AFCEE with the chemical analyses of any drilling mud additive or substitute proposed for use prior to the start of drilling. The additives or substitutes shall be analyzed for all analytes of concern at the site. The analyses shall be delivered to the AFCEE for written approval prior to drilling system mobilization. Mud or other additives shall only be used as a last resort.

Lubricants shall not introduce or mask contaminants. The contractor shall provide chemical analyses of all lubricants proposed for downhole use. Chemical detection limits shall be equivalent to those used in analyzing project ground-water samples. Lubricants with constituents that are toxic or that increase, decrease, or mask the target chemical species of the investigation shall not be permitted. The contractor shall provide the analysis results to the AFCEE prior to drilling mobilization.

A log of drilling activities shall be kept in a bound field notebook. Information in the log book shall include location, time on site, personnel and equipment present, down time, materials used, samples collected, measurements taken, and any other observations or information that would be necessary to reconstruct field activities at a later date. At the end of each day of drilling the drilling supervisor shall complete a Daily Drilling Log. An example of the Daily Drilling Log is shown in Section 8.0. All items on the log must be completed, if known.

The contractor shall dispose of all trash, waste grout, cuttings, and drilling fluids as coordinated with the base civil engineer or his representative

5.5.2 Sampling and Logging

The lithology in all boreholes shall be logged. The boring log form, in Section 8.0, shall be used for recording the lithologic logging information. Information on the boring log sheet includes the borehole location; drilling information; sampling information such as sample intervals, recovery, and blow counts; and sample description information.

Unconsolidated samples for lithologic description shall be obtained at each change in lithology or every five (5) foot interval, whichever is less or as specifically stated in the SOW. Lithologic descriptions of unconsolidated materials encountered in the boreholes shall generally be described in accordance with American Society for Testing and Materials (ASTM) D-2488-90 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM, 1990). Descriptive information to be recorded in the field shall include: (1) identification of the predominant particles size and range of particle sizes, (2) percent of gravel, sand, fines, or all three, (3) description of grading and sorting of coarse particles, (4) particle angularity and shape, and (5) maximum particle size or dimension.

Plasticity of fines description include: 1) moisture (dry, wet, or moist), 2) consistency of fine-grained soils, (3) structure of consolidated materials, and (4) cementation (weak, moderate, or strong).

Identification of the Unified Soil Classification System (USCS) group symbol shall be used. Additional information to be recorded includes the depth to the water table, caving or sloughing of the borehole, changes in drilling rate, depths of laboratory samples, presence of organic materials, presence of fractures or voids in consolidated materials, and other noteworthy observations or conditions, such as the locations of geologic boundaries.

Lithologic descriptions of consolidated materials encountered in the boreholes shall generally be described in accordance with Section 5.1. Consolidated samples for lithologic description shall be obtained at each change in lithology or at five-foot intervals, whichever is less, or as specified in the SOW. All samples shall be monitored with an organic vapor monitor (e.g., PID, organic vapor analyzer [OVA]). The samples shall be handled in such a way as to minimize the loss of volatiles, and these procedures shall be described in Section 6.0. Cuttings shall be examined for their hazardous characteristics. Materials suspected to be hazardous because of abnormal color, odor, or organic vapor monitor readings shall be containerized in conformance with the Resource Conservation and Recovery Act (RCRA) and the state and local requirements. Rock cores shall be stored in standard core boxes, and missing sections of core shall be replaced with spacers.

Lithologic descriptions of consolidated materials shall follow the specifications in Section 5.1.

5.5.3 Abandonment

The prime contractor shall identify, in addition to what is already described in this section, the specific procedures for abandonment of boreholes.

Boreholes that are not converted to monitor wells shall be abandoned in accordance with applicable federal, state and local requirements. If a slurry is used, a mud balance and/or Marsh Funnel shall be used to ensure the density (lbs/gal) of the abandonment mud mixture conforms to the manufacturer's specifications. The slurry shall be emplaced from the bottom to the top of the hole using a grout pump and tremie pipe.

All abandoned boreholes shall be checked 24 to 48 hours after mud/solid bentonite emplacement to determine whether curing is occurring properly. More specific curing specifications may be recommended by the manufacturer and shall be followed. If settling has occurred, a sufficient amount of mud/solid bentonite shall be added to fill the hole to the ground surface. These curing checks and any addition of mud/solid bentonite shall be recorded in the field log.

5.6 MONITOR WELL CONSTRUCTION

The prime contractor shall identify, in addition to what is already described in this section, the methods and material of construction, schedule, diameter, screen slot size, etc., for monitor well construction. Also, describe the criteria to be used to determine the placement of the well screen, and the method and duration of well development.

The on-site field manager shall supervise the drilling, soil boring, geophysical surveys, lithologic sampling, and monitor well construction and shall be a state-licensed geologist, hydrogeologist, or geotechnical engineer, or shall be certified by the American Institute of Hydrology, American Institute of Professional Geologists, or the National Ground Water Association as a Certified Ground Water Professional. The supervising field manager shall affix his/her signature and registration/certification seal to all drilling logs, as-built well construction diagrams, lithologic logs, sampling records, and similar documents.

When there is a possibility that floating petroleum products (i.e., light non-aqueous phase liquids, LNAPLs) may be encountered, shallow monitor wells shall be screened across the water table. The length of the screen shall be such that tidal and/or seasonal water-table fluctuations shall not cause water levels to rise above or fall below the screened interval. If dense petroleum products (i.e., dense non-aqueous phase liquids [DNAPLs]) may be encountered, monitor wells shall be screened at the bottom of the aquifer to capture the DNAPL.

AFCEE/ER highly recommends that all pertinent data pertaining to new monitor wells (e.g., location (state-plane coordinates), top-of-casing elevation, static water level, construction, stratigraphy of screened interval, and aquifer test data) be loaded into ERPIMS and submitted to AFCEE/MSC. This will help ensure that these important well and hydrogeologic data are readily available to all interested Air Force agencies and personnel currently and in the future.

5.6.1 Drilling Requirements

All drilling and well installations shall conform to state and local regulations, and the contractor shall obtain and pay for all permits, applications, and other documents required by state and local authorities. The location of all borings shall be coordinated in writing with the base civil engineer or equivalent before drilling commences.

The rig shall be cleaned and decontaminated according to the guidelines described in Section 5.12. The rig shall not leak any fluids that may enter the borehole or contaminate equipment that is placed in the hole. The use of rags or absorbent materials to absorb leaking fluids is unacceptable. The only acceptable drilling fluids are air, water, and mud. The air used shall be filtered to remove organic vapors, and if water is used, the prime contractor shall provide chemical analyses of the water showing the purity. The water quality shall be monitored daily for suspected analytes of concern. The mud used shall be 100 percent sodium bentonite. and the contractor shall provide chemical analyses of any drilling mud additive or substitute (e.g., foam, biodegradable material) proposed for use. The additives or substitutes for drilling shall be analyzed for all analytes of concern at the site and they shall be approved prior to drilling mobilization.

When air is used, the effectiveness of the air filter shall be checked at least every four hours. The air passing through the downstream end of the air line shall be monitored with an organic vapor monitor (e.g., PID, OVA), and if organic vapors are detected, their source (e.g., filter, contaminated line) shall be decontaminated or replaced.

Drilling lubricants shall not introduce or mask contaminants at the site. The contractor shall provide, to AFCEE, chemical analyses of all lubricants proposed for downhole use prior to the start of drilling. Chemical detection limits shall be equivalent to those used in analyzing the project ground-water samples. Lubricants with constituents that are toxic or that increase, decrease, or mask the target chemical species of the investigation shall not be permitted. The contractor shall provide the analysis results prior to drilling mobilization.

The contractor shall dispose of all trash, waste grout, cuttings, and drilling fluids as coordinated with the base civil engineer or representative. When installing wells through more than one water-bearing zone or aquifer, the contractor shall take measures to prevent cross-connection or cross-contamination of the zones or aquifers.

5.6.2 Borehole Requirements

Borehole diameters shall be at least four inches larger than the outside diameter of the casing and well screen. In the case of a hollow stem auger, the inside diameter of the auger shall be at least four inches larger than the outside diameter of the casing and well screen.

A completed monitor well shall be straight and plumb. The monitor well shall be sufficiently straight to allow passage of pumps or sampling devices. The monitor well shall be plumb within 1 degree of vertical where the water level is greater than 30 feet below land surface unless otherwise approved by AFCEE. AFCEE may waive a plumbness requirement. Any request for a waiver from straightness or plumbness specifications shall be made, in writing, to AFCEE in advance of mobilization for drilling. The contractor shall use a single-shot declination tool to demonstrate plumbness. Monitor wells not meeting straightness or plumbness specifications shall be redrilled and/or reconstructed.

Formation samples for lithologic description shall be obtained at each change in lithology or at five-foot intervals, whichever is less, or as specified in the SOW. All samples shall be monitored with an organic vapor monitor (e.g., PID, OVA). The samples shall be handled in such a way as to minimize the loss of volatiles, and these procedures shall be described in Section 6.0. Cuttings shall be examined for their hazardous characteristics. Materials that are suspected to be hazardous because of abnormal color, odor, or organic vapor monitor readings shall be containerized in conformance with RCRA and the state and local requirements. Rock cores shall be stored in standard core boxes, and missing sections of core shall be replaced with spacers.

The documentation record and forms, Section 8.0, shall document the following information for each boring: (1) boring or well identification (this identification shall be unique, and the contractor is responsible for ensuring it has not been used previously at the installation.), (2) purpose of the boring (e.g., soil sampling, monitor well), (3) location in relation to an easily identifiable landmark, (4) names of drilling contractor and logger, (5) start and finish dates and times, (6) drilling method, (7) types of drilling fluids and depths at which they were used, (8) diameters of surface casing, casing type, and methods of installation, (9) depth at which saturated conditions were first encountered, (10) lithologic descriptions and depths of lithologic boundaries, (11) sampling-interval depths, (12) zones of caving or heaving, (13) depth at which drilling fluid was lost and the amount lost, (14) changes in drilling fluid properties, (15) drilling rate, and (16) drilling rig reactions, such as chatter, rod drops, and bouncing.

In addition to the above, the following information shall be recorded when rock core samples are collected: (1) the depth interval and top and bottom of each core shall be marked on the core box, (2) percentage of core recovered, (3) number of fractures per foot, (4) angle of fractures relative to the core axis, and (5) breaks due to coring and core handling shall be distinguished from naturally occurring fractures.

A standard penetration test shall be performed each time a split spoon sample is taken. The test shall be performed in accordance with ASTM D-1586.

5.6.3 Casing Requirements

The casing requirements that shall be followed are: (1) all casing shall be new, unused, and decontaminated according to the specifications of Section 5.12, (2) glue or solvent shall not be used to join casing, and casings shall be joined only with water-tight flush-joint threads or thermal welds that shall not interfere with the planned use of the well, (3) Pop rivets or screws should not be used on casings or other monitoring well components, (4) all polyvinyl chloride (PVC) shall conform to the ASTM Standard F-480-88A or the National Sanitation Foundation Standard 14 (Plastic Pipe System), (5) all metal casing shall be seamless stainless steel casing, and the casing "mill" papers shall be included in the appendix of the technical report, (6) the casing shall be straight and plumb within the tolerance stated for the borehole, and (7) the driller shall cut a notch in the top of the casing to be used as a measuring point for water levels.

5.6.4 Well Screen Requirements

Well screen requirements are: (1) all requirements that apply to casing shall also apply to well screen, except for strength requirements, (2) monitor wells shall not be screened across more than one water-bearing unit, (3) screens shall be factory slotted or wrapped, (4) screen slots shall be sized to prevent 90 percent of the filter pack from entering the well, and for wells where no filter pack is used, the screen slot size shall be selected to retain 60 to 70 percent of the formation materials opposite the screen, and (5) the bottom of the screen is to be capped, and the cap shall be joined to the screen by threads.

To narrow the interval of aquifer being sampled, to limit the potential for stagnant or no-flow areas near the screen, and to preclude unwanted backfill material (e.g., grout, bentonite) from entering the screened interval, bottoms of well screens should be placed no more than three (3) feet above the bottom of the drilled borehole. If significant overdrilling is required, a pilot boring should be drilled.

In most hydrogeologic settings, screen lengths should not exceed 10 feet. The use of shorter well screens allows for contaminant detection by reducing excessive dilution. Additionally, when placed at depths of predicted preferential flow, shorter well screen are effective in monitoring the aquifer or the portion of the aquifer of concern. Longer well screens that span more than a single saturated zone or a single contaminant migration pathway may cause cross contamination of transmissive units, thereby increasing the extent of contamination. The use of screen lengths greater than 10 feet should be approved by the AFCEE Team Chief.

Multiple monitoring wells (well clusters (or nested wells) or single wells with multilevel sampling devices) should be installed at a single location when: (1) a single well cannot adequately intercept and monitor the vertical extent of a potential pathway of contaminant migration; or (2) more than one potential pathway of contaminant migration occurs at a single location; or (3) a thick saturated zone occurs and an immiscible contaminant(s) is present, or is determined to potentially occur at the site.

The contractor may propose open-hole wells in bedrock where cave-in is unlikely. Prior approval for such wells shall be obtained, in writing, from AFCEE.

5.6.5 Annular Space Requirements

The annular apace requirements are the following: (1) the annular space shall be filled with a filter pack, a bentonite seal, and casing grout between the well string and the borehole wall, (2) any drilling fluids shall be thinned with potable water of known acceptable quality to a density less than 1.2 g/cm^3 (10 lbs/gal) before the annular space is filled, and a mud balance or Marsh Funnel shall be kept on site to allow measurement of drilling fluid density, (3) as the annular space is being filled, the well string shall be centered and suspended such that it does not rest on the bottom of the hole, and (4) for wells greater than 40 feet deep, at least two centralizers shall be used, one at the bottom of the screen or silt trap, if present, and at each 30-foot vertical interval. (This requirement does not apply to wells constructed inside hollow-stem augers.) Centralizers should be oriented to allow for the unrestricted passage of the tremie pipe(s) used for filter pack and grout placement.

5.6.6 Filter Pack Requirements

The filter pack shall consist of silica sand or gravel and shall extend from the bottom of the hole to at least two feet above the top of the well screen. After the filter pack is emplaced, the well shall be surged with a surge block for ten minutes. The top of the sand pack shall be sounded to verify its depth during placement. Additional filter pack shall be placed as required to return the level of the pack to two feet above the screen. Surge the well for five minutes. Again, place additional filter pack as required to bring its level to two feet above the screen. If gravel is used, six inches of coarse sand shall be placed on top of the gravel.

The filter pack material shall be clean, inert, and well-rounded and shall contain less than two percent flat particles. The sand or gravel shall be certified free of contaminants by vendor or contractor. If decontamination is necessary, the methods shall be approved in writing by AFCEE.

The filter pack shall have a uniform, well-sorted grain size and uniformity coefficient compatible with the formation materials and the screen, as described in Chapter 12, *Ground Water and Wells*, 2nd Edition, 1986. AFCEE recommends that the uniformity coefficient not exceed 2.5. The filter pack shall not extend across more than one water-bearing unit. In all wells (deep or shallow), the filter pack shall be emplaced with a bottom-discharge tremie pipe of at least 1-1/2 inches in diameter. The tremie pipe shall be lifted from the bottom of the hole at the same rate the filter pack is set. The contractor shall record the volume of the filter pack emplaced in the well. Potable water may be used, with the approval of the regulatory agency providing oversight, to emplace the filter pack so long as no contaminants are introduced. The contractor may use formation materials as a filter pack when they are compatible with the slot size of the screen, such as in glacial outwash gravel deposits.

5.6.7 Bentonite Seal Requirements

The bentonite seal requirements that shall be followed are the following:(1) the bentonite seal shall consist of at least two feet of bentonite between the filter pack and the casing grout, (2) the bentonite shall be hydrated before placement and shall be installed by pump tremie methods, and (3) only 100 percent sodium bentonite shall be used.

For wells less than fifteen feet, the contractor may propose alternate sealing methods. Prior approval for any alternate method shall be obtained, in writing, from AFCEE before well construction begins.

5.6.8 Casing Grout Requirements

The casing grout requirements are the following: (1) the casing grout shall extend from the top of the bentonite seal to ground surface, (2) the grout shall be mixed in the following proportions: 94 pounds of neat Type I Portland or American Petroleum Institute Class A cement, not more than 4 pounds of 100 percent sodium bentonite powder, and not more than 8 gallons of potable water, (3) all grout shall be pump tremied using a side-discharge tremie pipe, and pumping shall continue until 20 percent of the grout has been returned to the surface to ensure the grout job is done properly and surface contaminants will not enter the annulus, (4) in wells where the bentonite seal is visible and within 30 feet of the land surface, the 20 percent return is not necessary so long as the tremie pipe is pulled back as the grout is emplaced, and, (5) the excess grout (20%) shall be removed and cleaned from the site prior to installing the pad.

5.6.9 Surface Completion Requirements

For flush-mounted completions, cut the casing about three inches below the land surface and provide a water-tight casing cap to prevent surface water from entering the well. To allow for escape of gas, a small diameter (e.g., 1/4-inch) vent hole shall be placed in the upper portion of the casing, or a ventilated well cap shall be used. A freely draining valve box with a locking cover shall be placed over the casing. The top of the casing shall be at least one foot above the bottom of the box. The valve box lid shall be centered in a three-foot diameter, four-inch thick concrete pad that slopes away from the box at 1/4 inch per foot. The identity of the well shall be permanently marked on the valve box lid and the casing cap. Where heavy traffic may pass over the well or for other reasons, the concrete pad and valve box/lid assembly shall be constructed to meet the strength requirements of surrounding surfaces.

When aboveground surface completion is used, extend the well casing two or three feet above land surface. Provide a casing cap for each well, and shield the extended casing with a steel sleeve that is placed over the casing and cap and seated in a 3-foot by 3-foot by 4-inch concrete surface pad. To allow for escape of gas, a small diameter (e.g., 1/4-inch) vent hole shall be placed in the well casing, or a ventilated well cap shall be used. The concrete surface pad shall be reinforced with steel reinforcing bars at least 1/4 inch in diameter. The ground surface shall be freed of grass and scoured to a depth of two inches before setting the concrete pad. The diameter of the sleeve shall be at least six inches greater than the diameter of the casing. Slope the pad away from the well sleeve. Install a lockable cap or lid on the guard pipe. The identity of the well shall be permanently marked on the casing cap and the protective sleeve. Install three 3-inch diameter concrete-filled steel guard posts. The guard posts shall be five feet in total length and installed radially from each wellhead. Recess the guard posts approximately two feet into the ground and set in concrete. Do not install the guard posts in the concrete pad placed at the well base. The protective sleeve and guard posts shall be painted with a color specified by the installation civil engineer. In areas subject to significant frost heave, AFCEE recommends placing a bentonite surface seal with six (6)-inch minimum thickness adjacent to the protective casing and sloped to direct surface-water drainage away from the well. The top of this seal should terminate two (2) inches below the land surface and should be covered with topsoil or native soil to prevent drying out.

The contractor may propose alternate surface completion methods to address various soil conditions specific to the site. Prior approval for any alternate method shall be obtained, in writing, from AFCEE before well construction begins.

All wells shall be secured as soon as possible after drilling. Provide corrosion-resistant locks for both flush and above-ground surface completions. The locks must either have identical keys or be keyed for opening with one master key. Deliver the lock keys to the appropriate Air Force personnel following completion of the field effort.

5.6.10 Piezometer Requirements

A piezometer is a small diameter cased borehole primarily used for water level measurements. The piezometers' requirements are the following: (1) piezometers shall be constructed using methods or materials that do not contaminate groundwater or allow hydraulic communication between water-bearing units or between the ground surface and water-bearing units, (2) piezometers that penetrate more than one water-bearing unit shall be constructed in a manner that allows fluid from only one unit to enter them, and (3) the straightness and plumbness of piezometers shall be the same as for boreholes and monitor wells, Section 5.6.2. Required piezometer completion information shall be all applicable information enumerated in Section 5.6.2, paragraph four.

5.6.11 Well/Piezometer Completion Diagrams

A completion diagram shall be submitted for each monitor well or piezometer installed. It shall include the following information: (1) well identification (this shall be identical to the boring identification described), (2) drilling method, (3) installation date(s), (4) elevations of ground surface and the measuring point notch, (5) total boring depth, (6) lengths and descriptions of the screen and casing, (7) lengths and descriptions of the filter pack, bentonite seal, casing grout, and any back-filled material, (8) elevation of water surface before and immediately after development, and (9) summary of the material penetrated by the boring.

5.6.12 Suction Lysimeters

Pressure-vacuum lysimeters shall be installed in 4-inch (nominal) diameter borings to sample soil moisture in the unsaturated zone. No fluids or air shall be used to advance the borings. The excavated soil shall be saved for use in backfilling and not allowed to dry. Soil excavated from the bottom 6 inches of the boring shall be loosened, and pebbles greater than 1/4 inch in diameter shall be removed. The soil shall be placed around the porous cup and tamped to ensure intimate contact between the cup and soil.

Soil slurries shall not be placed around the porous cup. If a slurry is necessary, Reagent-Grade II Water shall be used. The volume of water added shall be recorded. At a minimum, the volume of slurry shall be drawn and discarded before samples are taken for analysis. In all cases where a slurry is used, the first volume of sample that enters the lysimeter shall be discarded.

Excavated soil shall be backfilled in the horizon from which it came and tamped to a density approximating its undisturbed condition. The soil shall be backfilled in lifts not greater than one foot. A 3-inch thick bentonite plug shall be placed 6 inches below land surface to prevent fluids from running down the boring. The porous cups shall be saturated with Reagent-Grade II Water at the time of installation so that gas shall not enter the sampler. The cup may be saturated by placing an evacuated lysimeter in a container of water. The saturated cups may be stored for several hours in a glass jar with Teflon® lid containing some Reagent-Grade II Water.

All lysimeters and associated equipment (e.g., pump used to expel sample) shall be decontaminated according to the specifications in Section 5.12. Samples collected from suction lysimeters shall be preserved and handled the same as ground-water samples.

In addition to the information required in Section 8.0, the following information shall be recorded: (1) the depth at which the porous cup is installed, (2) the final pressure at the time the lysimeter is evacuated and the pressure at the time the lysimeter is sampled, (3) the time between lysimeter evacuation and sampling and, (4) instrument calibrations.

5.7 MONITOR WELL DEVELOPMENT

The monitor well development requirements are: (1) all newly installed monitor wells shall be developed no sooner than 24 hours after installation to allow for grout curing, (2) all drilling fluids used during well construction shall be removed during development, (3) wells shall be developed using surge blocks and bailers or pumps (prior approval for any alternate method shall be obtained, in writing, from AFCEE before well construction begins), and wells shall be developed until: (a) the suspended sediment content of the water is less than 0.75 mL/L, as measured in an Imhoff cone according to method E160.5; (b) the turbidity remains within a 10 nephelometric turbidity unit range for at least 30 minutes; and (c) the stabilization criteria in Section 6.1.1.1.3 are met, (4) discharge water color and volume shall be documented, (5) no sediment shall remain in the bottom of the well, (6) no detergents, soaps, acids, bleaches, or other additives shall be used to develop a well, and (7) all development equipment shall be decontaminated according to the specifications of Section 5.12.

AFCEE recommends that a well recovery test be performed immediately after and in conjunction with well development. This recovery test provides: (1) an indication of well performance; and (2) data for determining the transmissivity and hydraulic conductivity of the screened hydrogeologic unit. Water-level readings should be taken at intervals suggested in the table below until the well has recovered to at least 80 percent of its static (pretest) water level, or for a reasonable time frame not to exceed 10 hours. The recovery test data and results should be loaded into ERPIMS and submitted to AFCEE/MSC.

Time Since Starting Test	Measurement Time Interval
0 to 15 min	1 min
15 to 50 min	5 min
50 to 100 min	10 min
100 to 300 min	30 min
300 to 600 min	60 min

5.8 ABANDONING MONITOR WELLS

The prime contractor shall identify, in addition to what is already described in this section, the specific procedures for abandonment of wells.

All abandonment of monitor wells directed by AFCEE shall be performed in accordance with federal, state and local laws and regulations. The well should be cleared of all obstructions prior to abandonment. Obstructions such as pumps, pipes, wiring, and air lines must be pulled. An attempt should be made to pull the casing when it will not jeopardize the integrity of the borehole. Before the casing is pulled, the well should be grouted to near the bottom of the casing. This will at least provide some seal if the well collapses after the casing is pulled.

If slurry is used to seal the well, a mud balance and/or Marsh Funnel shall be used to ensure that the density (lbs/gal) of the abandonment mud mixture conforms to the manufacturer's specification. All abandoned monitor wells shall be checked 24 to 48 hours after mud/solid bentonite emplacement to determine whether curing is occurring properly. More specific curing specifications or quality assurance checks may be recommended by the manufacturer and shall be followed. Additionally, if significant settling has occurred, a sufficient amount of mud/solid bentonite shall be added to attain its initial level. These slurry/solid bentonite curing checks and any addition of mud/solid bentonite shall be recorded in the field logs.

Copies of all completed field logs should be submitted to the AFCEE COR. Additionally, the ERPIMS well records for all wells abandoned should be modified to annotate abandonment and the updated electronic well records submitted to AFCEE/MSC.

5.9 AQUIFER TESTS

The prime contractor shall describe the equipment to be used, including calibration and QC requirements for the aquifer tests. Include the method for calculating aquifer characteristics.

5.9.1 Aquifer Testing For Hydraulic Properties

5.9.1.1 General

Equipment shall be decontaminated and water levels measured according to the specifications of Sections 5.12. The contractor shall demonstrate that the assumptions of the selected analytical methods for deriving the hydraulic properties match the hydrogeological conceptual site model, and meet the data quality objectives in Section 3.0.

5.9.1.2 Slug Tests

Slug tests are applicable to rocks or unconsolidated deposits of low to moderate hydraulic conductivity. Testing of several wells is necessary to characterize an aquifer because slug tests only measure aquifer properties immediately adjacent to the borehole or well. The water level shall be static before the test begins. That is, it must not be recovering or receding as a result of sampling, development, pumping of nearby wells, or related activities. The test shall be performed using a slug or by withdrawing water from the well. No fluid shall be put in the well.

When designing a slug test, the geologist should keep in mind the following criteria: (1) volume of the slug, (2) diameter of the well, (3) depth and length of the screened interval, (4) method and frequency of water level measurements, (5) barometric pressure and, (6) the method used to analyze the data. If the static water level is below the top of the screen or open section of the well, a falling-head test should not be performed. The slug test shall continue until the water level has recovered to at least 80 percent of its static (pretest) level.

All valid water-level or drawdown versus time data resulting from these tests should be appended to the draft and final reports describing the analysis of these tests. These field data should be provided in ASCII electronic format. Additionally, these field data and the calculated hydraulic conductivity values should be loaded into ERPIMS and submitted to AFCEE/MSC.

5.9.1.3 Pumping Tests

The contractor shall use monitor wells as observation wells as much as possible. The pumping rate shall be determined by conducting step-drawdown tests prior to the pumping test. The well shall be pumped at predetermined rates in order to determine the optimum pumping rate. If a lower pumping rate is preferable because of factors such as nearby supply wells, areas with floating product, disposal costs, or limited storage facilities, the lower rate shall be approved by AFCEE. In addition, barometric pressures should be monitored at the beginning and at least at the end of the test to evaluate the impact barometric pressure may have on the test. The test shall not begin until water levels in all wells have completely recovered. The contractor shall monitor and regulate the discharge valve for either a constant-discharge or constant-head test. The discharge rate shall be measured at least ten times during the first 100 minutes of the test and at least every time water levels are measured thereafter. Discharge rates shall be measured in accordance with Section 7.4.3. Water levels shall be measured at least ten times per log cycle for the first 100 minutes of the test and at least once every hour thereafter. The pumped water shall be disposed of so as not to recharge the portion of the aquifer being tested or otherwise affect the validity of the test. Time-drawdown or distance-drawdown data shall be analyzed during the test. The test shall be terminated when collection of additional data shall not affect results (e.g., when water levels are essentially at equilibrium, or when a well in low hydraulic conductivity rocks does not yield sufficient water to continue). Test durations may range from two hours to a week or more. A common test period is 24 hours.

All valid water-level or drawdown versus time data resulting from these tests should be appended to the draft and final reports describing the analysis of these tests. These field data should be in ASCII electronic format. Additionally, these field data and the calculated hydraulic parameter values should be loaded into ERPIMS and submitted to AFCEE/MSC.

5.9.1.4 Other Test Methods

The aquifer hydraulic parameters can be estimated from well specific capacity and from step-drawdown tests. For low hydraulic conductivity rocks, ASTM D-4630 or D-4631 is applicable. For clay, ASTM D-1587 and D-2434 are applicable.

5.10 TEST PIT EXCAVATION

The prime contractor shall describe, in addition to what is already described in this section, the dimensions of test pits, method of excavation (e.g., shovel or backhoe), and method of shoring (if applicable).

A test pit is an opening in soil, unconsolidated deposit, or bedrock having at least one lateral dimension greater than the depth of the opening, which is used for scientific purposes. The location of each test pit shall be coordinated in writing with the base civil engineer before digging begins. The contractor shall follow Occupational Safety and Health Administration (OSHA) rules for excavation and confined space entry. The excavated material shall be screened for hazardous properties. Nonhazardous excavated material shall be backfilled immediately after the required information has been recorded. The first soils out shall be the last in when filling the pit. No test pit shall be left open overnight unless adequate safety precautions are employed. In vegetated areas, backfilled test pits shall be reseeded with native grasses. In addition to the general information required for all field activities listed in Section 8.0, the following shall be recorded for each test pit: (1) the total depth, length, and width, (2) the depth and thickness of distinct soil or lithologic units, (3) a lithologic description of each unit, and (4) a description of any man-made materials or apparent contamination encountered.

Excavation shall occur by using either a backhoe or hand shovel. Decontamination of all equipment shall occur after an excavation is completed or daily following the procedures described in Section 5.12. Any shoring that is required shall be described and documented. The dimensions for all test pits that shall be excavated shall be described in Section 3.0.

5.11 SURVEYING

The prime contractor shall describe, in addition to what is already described in this section, the specific survey method, bench mark and accuracy that shall be used for this project.

All surveying locations of field activities shall be measured by a certified land surveyor as the distance in feet from a reference location that is tied to the state plane system. The surveys shall be third order (cf. Urquhart, L.C., *1962 Civil Engineering Handbook*, 4th Edition, ps. 96 and 97). An XY-coordinate system shall be used to identify locations. The X coordinate shall be the East-West axis; the Y coordinate shall be the North-South axis. The reference location is the origin. All surveyed locations shall be reported using the state plane coordinate system. The surveyed control information for all data collection points shall be recorded and displayed in a table. The table shall give the X and Y coordinates in state plane coordinate values, the ground-surface elevation, and the measuring point elevation if the location is a ground-water monitor well. The elevation of all newly installed wells and piezometers shall be surveyed at the water level measuring point (notch) on the riser pipe. Surveyed elevations should be referenced to mean sea level. X and Y coordinates should be reported to no more than one decimal place. Z coordinates (elevations) should be reported to no more than two decimal places. All monitoring wells shall be resurveyed at a minimum every five years, with the approval of AFCEE.

5.12 EQUIPMENT DECONTAMINATION

The prime contractor shall describe all decontamination of drilling equipment, well construction materials, sampling equipment, tools, and all other applicable equipment. Describe how and where decontamination of equipment will be performed.

All equipment that may directly or indirectly contact samples shall be decontaminated in a designated decontamination area. This includes casing, drill bits, auger flights, the portions of drill rigs that stand above boreholes, sampling devices, and instruments, such as slugs and sounders. In addition, the contractor shall take care to prevent the sample from coming into contact with potentially contaminating substances, such as tape, oil, engine exhaust, corroded surfaces, and dirt.

The following procedure shall be used to decontaminate large pieces of equipment, such as casings, auger flights, pipe and rods, and those portions of the drill rig that may stand directly over a boring or well location or that come into contact with casing, auger flights, pipe, or rods. The external surfaces of equipment shall be washed with high-pressure hot water and Alconox, or equivalent laboratory-grade detergent, and if necessary, scrubbed until all visible dirt, grime, grease, oil, loose paint, rust flakes, etc., have been removed. The equipment shall then be rinsed with potable water. The inside surfaces of casing, drill rod, and auger flights shall also be washed as described.

The following procedure shall be used to decontaminate sampling and drilling devices, such as split spoons, bailers, and augers that can be hand-manipulated. For sampling and smaller drilling devices, scrub the equipment with a solution of potable water and Alconox, or equivalent laboratory-grade detergent. Then rinse the equipment with copious quantities of potable water followed by ASTM Type II Reagent Water. High-pressure liquid chromatograph-grade water and distilled water purchased in stores are not acceptable substitutes for ASTM Type II Reagent-Grade Water. (If equipment has come in contact with oil or grease, rinse the equipment with pesticide-grade methanol followed by with pesticide-grade hexane.) Air dry the equipment on a clean surface or rack, such as Teflon®, stainless steel, or oil-free aluminum elevated at least two feet above ground. If the sampling device shall not be used immediately after being decontaminated, it shall be wrapped in oil-free aluminum foil, or placed it in a closed stainless steel, glass, or Teflon® container.

Reagent-Grade II Water, methanol, and hexane shall be purchased, stored, and dispensed only in glass, stainless steel, or Teflon® containers. These containers shall have Teflon® caps or cap liners. It is the contractor's responsibility to assure these materials remain free of contaminants. If any question of purity exists, new materials shall be used.

5.13 WASTE HANDLING

The prime contractor shall provide detailed procedures for handling and disposing of waste generated on site (e.g., well development fluids, equipment decontamination fluids, and disposable personal protective clothing).

5.13.1 General Waste Handling Procedures

Waste handling shall be dealt with on a site-by-site basis. Waste may be classified as noninvestigative waste or investigative waste

Noninvestigative waste, such as litter and household garbage, shall be collected on an as-needed basis to maintain each site in a clean and orderly manner. This waste shall be containerized and transported to the designated sanitary landfill or collection bin. Acceptable containers shall be sealed boxes or plastic garbage bags.

Investigation derived waste shall be properly containerized and temporarily stored at each site, prior to transportation. Depending on the constituents of concern, fencing or other special marking may be required. The number of containers shall be estimated on an as-needed basis. Acceptable containers shall be sealed, U.S. Department of Transportation (DOT)-approved steel 55-gallon drums or small dumping bins with lids. The containers shall be transported in such a manner to prevent spillage or particulate loss to the atmosphere. To facilitate handling, the containers shall be no more than half full when moved.

The investigative derived waste shall be segregated at the site according to matrix (solid or liquid) and as to how it was derived (drill cuttings, drilling fluid, decontamination fluids, and purged groundwater). Each container shall be properly labeled with site identification, sampling point, depth, matrix, constituents of concern, and other pertinent information for handling.

5.14 HYDROGEOLOGICAL CONCEPTUAL MODEL

The project geologist or engineer shall develop a Base/installation and site geological and hydrological conceptual model from pre-existing U.S. Geological Survey (USGS), regional, state, and local studies and information developed during the project. Maps and cross sections (see Figs 5-2 and 5-3 in Appendix C) shall be used to depict the conceptual model. The model shall be the basis for evaluating monitor well and piezometer locations, contaminant distribution (plume delineation), and the closeness of fit to natural conditions of analytical or computer-based numerical models.

5.14.1 Analytical or Numerical Model Representations of the Hydrogeological Conceptual Model

The project geologist or engineer shall be responsible for evaluating the fit of analytical or numerical ground-water flow and contaminant transport models to natural site conditions and the model's ability to predict the spatial and temporal distribution of contaminants. The model shall consider stratigraphy, geological structure, aquifer homogeneity or heterogeneity, hydraulic conductivity, transmissivity, storativity, and effective porosity. As applicable, the model shall consider leakage, dispersivity, and attenuation.

The project geologist or engineer shall evaluate the reliability of predictions resulting from use of the model. Reliability will be based on sufficiency and representativeness of field data, model calibration, degree of change of field data during calibration, and model sensitivity to changes in selected variables. The values assigned to nodes of numerical models and the amount of change in field values shall be displayed on maps or cross sections.

5.15 CORRECTIVE ACTION

The prime contractor shall describe the procedures used for corrective actions. Include: (1) the mechanism for triggering the initiation of corrective actions, (2) the procedures used for initiating, developing, approving and implementing corrective actions, and (3) the documentation process.

6.0 ENVIRONMENTAL SAMPLING

6.1 SAMPLING PROCEDURES

The prime contractor shall provide detailed descriptions of the methods and procedures to be used for collecting environmental samples from ground water, surface water, soil, sediment, air, and biological materials in this section that are not discussed or described completely in the following sections. The descriptions of the sampling procedures shall provide enough detail so a field team not familiar with the project could properly collect all samples.

In addition to the sampling methods discussed below the contractor may propose other sampling methods. These methods should be submitted to AFCEE for approval.

The construction material (e.g., plastic, PVC, metal) of the sampling devices discussed below shall be appropriate for the contaminant of concern and shall not interfere with the chemical analyses being performed.

All purging and sampling equipment shall be decontaminated according to the specifications in Section 5.12 prior to any sampling activities and shall be protected from contamination until ready for use.

6.1.1 Ground-water Sampling

6.1.1.1 Monitor Well Sampling

When numerous monitor wells are to be sampled in succession, those wells expected to have low levels of contamination or no contamination shall be sampled prior to those wells expected to have higher levels of contamination. This practice will help reduce the potential for cross contamination between wells. All sampling activities shall be recorded in the field logbook. Additionally, all sampling data shall be recorded on a well sampling form. A well sampling form is shown in Section 8.0.

Before ground-water sampling begins, wells shall be inspected for signs of tampering or other damage. If tampering is suspected, (i.e., casing is damaged, lock or cap is missing) this shall be recorded in the field logbook and on the well sampling form, and reported to the Field Operations Leader. Wells that are suspected to have been tampered with shall not be sampled until the Field Operations Leader has discussed the matter with the project manager.

Before the start of sampling activities, plastic sheeting shall be placed on the ground surrounding the well. The plastic sheeting shall be used to provide a clean working area around the wellhead, and prevent any soil contaminants from contacting sampling equipment. Remove water in the protective casing or in the vaults around the well casing prior to venting and purging. Every time a casing cap is removed to measure water level or collect a sample, the air in the breathing zone shall be checked with an organic vapor meter and the air in the well bore shall be checked with an explosimeter. Procedures in the Health and Safety Plan (HSP) shall be followed when high concentrations of organic vapors or explosive gases are detected. Air monitoring data shall be recorded on the well sampling form.

Purge pump intakes shall be equipped with a positive foot check valve to prevent purged water from flowing back into the well. Purging and sampling shall be performed in a manner that minimizes aeration in the well bore and the agitation of sediments in the well and formation. Equipment shall not be allowed to free-fall into a well.

In addition to the information required in Section 8.0, the following information shall be recorded each time a well is purged and sampled: (1) depth to water before and after purging, (2) well bore volume calculation, (3) sounded total depth of the monitor well, (4) the condition of each well, including visual (mirror) survey, (5) the apparent thickness of any nonaqueous layer and, (6) field parameters such as pH, temperature, specific conductance, DO, and turbidity. This information shall be encoded in IRP Environmental Resources Program Information Management System (ERPIMS) electronic files when required.

6.1.1.1.1 Water Level Measurement

An interface probe or weighted tape coated with commercially available reactive indicator paste shall be used if a nonconductive floating product layer is suspected in the well. The interface probe or tape coated with reactive indicator paste shall be used to determine the presence and thickness of floating product prior to measurement of the ground-water level. The ground-water level shall then be measured to the nearest 0.0l foot using an electric water-level indicator or weighted tape coated with chalk. Water levels shall be measured from the notch located at the top of the well casing and recorded on the well sampling form. If well casings are not notched, measurements shall be taken from the north edge of the top of the well casing, and a notch shall be made using a decontaminated metal file. Where measurable floating product (e.g., nonaqueous-phase liquid) is present, depressed water levels should be corrected to reflect true water levels.

Following water level measurement, the total depth of the well from the top of the casing shall be determined using a weighted tape or electric sounder and recorded on the well sampling form. The water level depth shall then be subtracted from the total depth of the well to determine the height of the water column present in the well casing. All water level and total depth measuring devices shall be routinely checked with a tape measure to ensure measurements are accurate.

6.1.1.1.2 Purging Prior to Sampling

Purging of monitor wells is performed to evacuate water that has been stagnant in the well and may not be representative of the aquifer. Purging shall be accomplished using a Teflon® bailer or a pump.

At least three well volumes shall be removed from the well before it is sampled. The well bore volume is defined as the volume of submerged casing and screen. One well volume can be calculated using the following equation (reference: Ohio EPA Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring Programs, June 1993):

$$V = H \times F$$

where V = one well volume
H = the difference between the depth of well and depth to water (ft)
F = factor for volume of one foot section of casing (gallons) from Table 6.1

Table 6.1 Volume of Water in One-Foot Section of Well Casing

Diameter of Casing (inches)	F Factor (gallons)
1.5	0.09
2	0.16
3	0.37
4	0.65
6	1.47

F can also be calculated from the formula:

$$F = \Pi \, (D/2)^2 \times 7.48 \text{ gal/ft}^3$$

where D = the inside diameter of the well casing (feet).

Wells with yields too low to produce three well volumes before the well goes dry shall be purged to dryness. To minimize pumping to dryness, pump rates should be reduced to 0.5 gallons per minute or less, and pumping times extended accordingly.

The water-quality stabilization parameters temperature, pH, electrical conductivity (EC), turbidity and dissolved oxygen (DO) shall be measured and recorded on the well sampling form after removing each well volume during purging. AFCEE recommends that purge water be pumped through an in-line flow-through cell containing measurement sensors for these four stabilization indicator parameters. Water removed from the well during purging shall be containerized. Detailed information concerning investigative derived wastes is presented in Section 5.13.

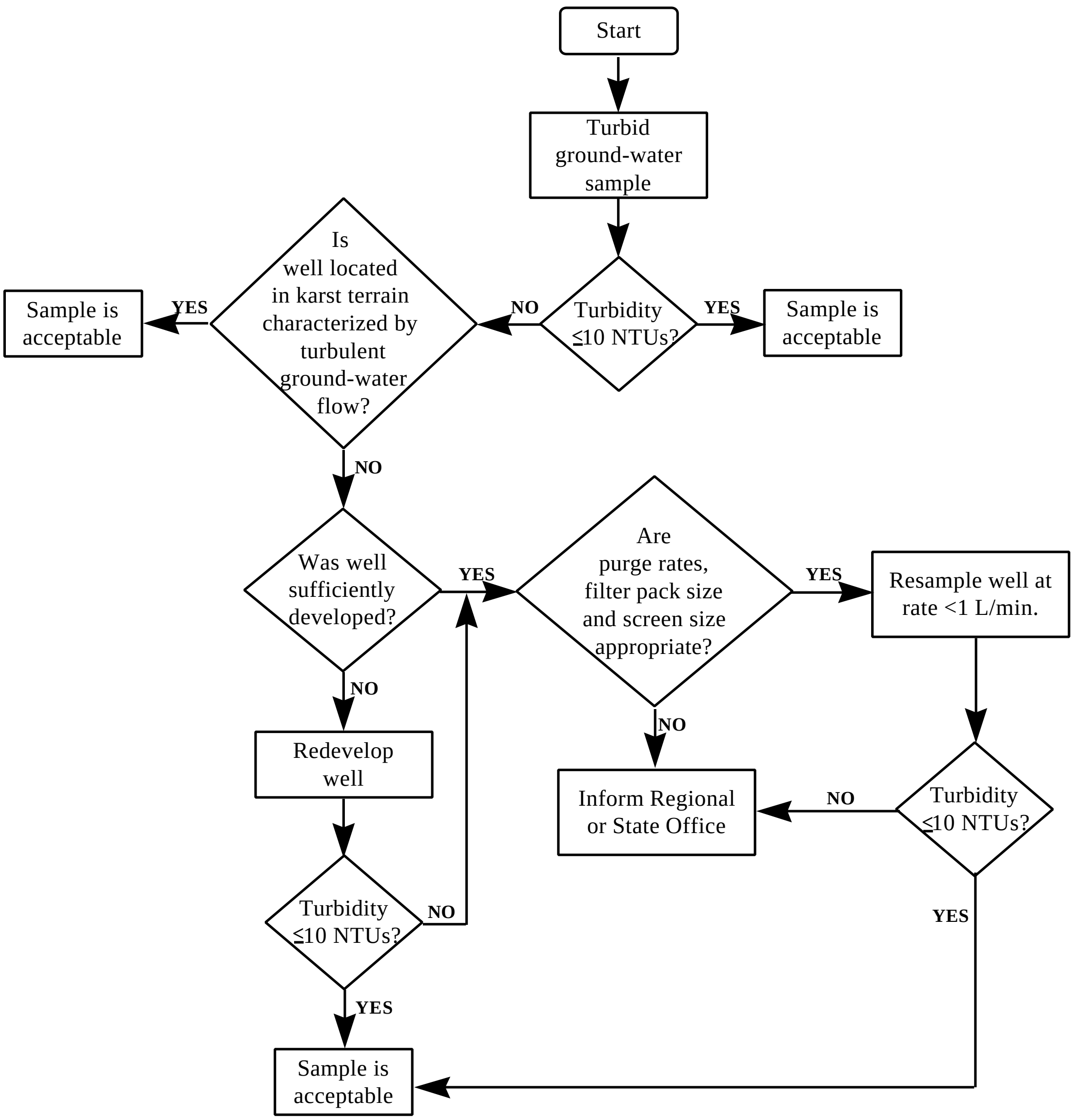
Micropurge is an acceptable procedure to use for AFCEE projects. Micropurge is a low flow-rate monitor well purging and sampling method that induces laminar (non turbulent) flow in the immediate vicinity of the sampling pump intake, thus drawing groundwater directly from the sampled aquifer horizontally through the well screen, and into the sampling device. This results in collecting groundwater from a discrete portion of the well screen at a rate that closely replicates the natural recharge of groundwater from the formation into the well screen. Pumping at flow rates in the approximate range of 0.2 to 2.0 liters/min while monitoring the water level within the well ensures minimal or essentially no drawdown. These low flow rates minimize disturbance in the screened aquifer, resulting in: (1) minimal production of artificial turbidity and oxidation; (2) minimal mixing of chemically distinct zones; (3) minimal loss of volatile organic compounds; and (4) collection of representative samples while minimizing purge volume. While the well is being purged, field parameters are monitored at the wellhead typically at 5- to 10-minute intervals using a flow-through cell.

6.1.1.1.3 Sample Collection

Samples shall not be taken within 24 hours of monitor well development. Except as noted below, at least three well volumes shall be removed from the well before it is sampled.

The sample may be collected after three well volumes have been removed and the temperature, pH, EC, turbidity, and DO have stabilized. However, when using micropurge methodology, removal of three well volumes is not required. Stabilization shall be defined as follows: temperature ± 1^{o}C, pH ± 0.1 units, EC ± 5 percent, turbidity ≤ 10 NTU, and DO ± 10 percent for successive readings. In addition, the decision chart for turbid ground-water samples (Figure 6-1) may be used. If these parameters do not stabilize, the sample shall be collected after five well volumes have been removed, and the anomalous parameters shall be brought to the Field Operations Leader's attention. Field equipment shall be calibrated in accordance with

Figure 6-1
Decision Chart for Turbid Ground-Water Samples



(Modified from U.S.E.P.A., *RCRA Ground-Water Monitoring: Draft Technical Guidance*, Figure 14)

(IAW) the AFCEE QAPP, Section 6.0 and Section 7.2 of this FSP.

Samples shall be collected after the water level has recovered to 80 percent of its static level or 16 hours after completion of purging, whichever occurs first. If a monitor well is bailed or pumped dry before three well volumes can be obtained, the sample shall be collected when a sufficient volume of water has accumulated in the well.

Micropurge sampling shall use small positive-displacement pumps (e.g., bladder pumps). Samples to be analyzed for volatile or gaseous constituents shall not be withdrawn with pumps or at flow rates that degas the samples. Water-quality indicator parameters (pH, turbidity, dissolved oxygen, specific conductance, and temperature) shall be monitored and recorded during micropurge sampling, preferably using an in-line flow-through cell.

Before collecting ground-water samples, the sampler shall don clean, phthalate-free protective gloves. Samples to be analyzed for volatile organic compounds (VOCs) shall be collected first using a bottom-filling Teflon® (preferred) or PVC bailer or positive-displacement pump (e.g., bladder pump). Samples to be analyzed for volatile or gaseous constituents shall not be withdrawn with pumps that exert a vacuum on the sample (e.g., centrifugal and peristaltic). Disposable nylon rope shall be used to lower and retrieve the bailers. A new length of nylon rope shall be used for each well, and the rope shall be disposed of following the sampling activities. Each bailer shall be equipped with a dedicated stainless steel or Teflon® coated leader so that the nylon rope shall not contact the water in the well.

Sampling equipment should be constructed of inert material, precluding alteration of analyte concentrations caused by sorption, desorption, degradation, or corrosion. Viton®, Tygon®, silicon and neoprene should not be components of sampling equipment that come into contact with the groundwater sample. These materials have been demonstrated to cause sorptive losses of contaminants, primarily VOCs.

If DNAPL is suspected, a bailer shall be lowered to the bottom of the well before purging, retrieved, and observed for the presence of DNAPL. The preservative hydrochloric acid shall be added to the VOC sample bottle before introducing the sample water. The sample shall be collected from the bailer using a slow, controlled pour down the side of a tilted sample vial to minimize volatilization. The sample vial shall be filled until a meniscus is visible and immediately sealed. When the bottle is capped, it shall be inverted and gently tapped to ensure no air bubbles are present in the vial. If, after the initial filling bubbles are present, the vials shall be discarded and the VOC sampling effort shall be repeated. Refilling of vials will result in loss of preservatives. After the containers are sealed, sample degassing may cause bubbles to form.

These bubbles shall be left in the container. These samples shall never be composited, homogenized, or filtered.

Following collection of VOC samples, remaining water samples shall be collected in the following order: SVOCs (semivolatile organic compounds), including polynuclear aromatic hydrocarbons (PAHs); metals; mercury; cyanide; total organic carbon; and anions/cations.

The pH of preserved samples shall be checked in the field by pouring a small amount of the water sample onto pH paper. The paper shall not touch the sample inside the container. Do not check the pH of acidified VOC samples. The preservation checks shall be documented in the chain-of-custody forms. One preserved VOC sample per day per sampling crew shall be checked with pH paper. The sole purpose of this sample is to check the pH of VOC samples; it shall not be submitted for analysis.

Water samples requiring filtering (i.e., those for metals analysis) shall be filtered through a 0.45 µm membrane filter immediately (within five minutes) after sampling and prior to preservation. Do not use vacuum filtration or any method that may aerate the samples. Exposure of samples to atmospheric oxygen shall be kept to a minimum. In-line filtration and use of disposable filter assemblies are preferred. Filters with larger pores may be used as pre-filters. If samples are filtered, the contractor shall prepare a blank by filtering Type II Reagent-Grade Water and submitting the blank for analysis for metals. This shall be done once per sampling round to assure that filtration does not bias sample results. Sample turbidity shall be recorded and reported.

Required sample containers, preservation methods, volumes and holding times are given in Section 6.2 and Table 6.2.2-1. Sampling equipment shall be decontaminated in accordance with Section 5.12 upon completion of sampling activities.

6.1.1.2 Direct Push Sampling

Direct push sampling involves advancing a sampling probe to the point below the water table from which the sample is desired. The probe can be advanced by direct hydraulic pressure or by using a slide or rotary hammer. When the probe is at the proper depth, sampling ports on the probe are opened, and the sample is collected using a bailer, by vacuum pressure or using the natural pressure of the formation. Samples collected for VOC analysis shall not be drawn by vacuum pressure. The advantage of this method is no drill cuttings are produced.

HydroPunch®, cone penetrometer (e.g., SCAPS) or Geoprobe® water samples are generally collected for on-site or quick-turnaround analysis to determine if the boring should be converted to a monitor well or to fill data gaps. These samples are not directly comparable to monitor well samples, because they are collected from disturbed conditions. HydroPunch® sampling is performed during drilling when the boring extends below the water table. With this method, a 2-inch diameter core is obtained by advancing a core sampler into the unconsolidated formation 3-5 feet below the water table using direct hydraulic pressure or a hydraulic hammer. The core is then retrieved, leaving a small borehole. The borehole is then completed as a temporary monitor well that can be sampled with a 1-inch diameter bailer or peristaltic pump, depending on depth. The temporary monitor well shall be sampled with a 1-inch diameter bailer.

6.1.2 Subsurface Soil Sampling

Soil samples shall be collected based on odors, discoloration, organic vapor meter readings and any other field screening method.

6.1.2.1 Split-Spoon Samples

When soil samples are to be submitted for laboratory analysis, they shall be collected using stainless steel, continuous drive, California modified split-spoon samplers, or equivalent. These samplers are 24 inches in length and have an outside diameter (OD) of 3 inches to accommodate four 2-inch diameter brass/stainless steel rings, each of which is 6 inches in length. Small diameter split-spoon samplers may be used with the approval of AFCEE.

Each time a split-spoon sample is taken, a standard penetration test shall be performed in accordance with ASTM D-1586 "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils." The sample is obtained by driving the sampler a distance of 1 foot into undisturbed soil with a 140-pound hammer free falling a distance of 30 inches. The sampler is first driven 6 inches to seat it in undisturbed soil; then the test is performed. The number of hammer blows for seating the spoon and making the test are then recorded for each 6 inches of penetration on the drill log (i.e., 5/7/8). The standard penetration test result (N) is obtained by adding the last two figures (i.e., 7+8=15 blows per foot). The sampler is then driven an additional 6 inches to fill the remainder of the split-spoon prior to retrieval.

As soon as the split-spoon is opened, the open ends of the brass/stainless steel rings shall be monitored for organic vapors using the PID or FID. Air monitor results shall be recorded on the boring log and in the field logbook. If initial screening results indicate the presence of organic vapors, a headspace analysis shall be conducted.

Samples for VOC analysis shall be collected as an entire brass/stainless steel ring sample or by using an EnCore™ or equivalent sampling device. Brass/stainless steel rings selected for VOC analysis shall be completely filled, if possible, to minimize headspace. Rings with large gravel or debris shall not be used. Following monitoring for organic vapors, the brass/stainless steel rings shall be capped on both ends with Teflon® sheeting and plastic end caps to prevent volatilization. The brass/stainless steel rings shall then be affixed with a completed sample label, placed in a zip lock plastic bag and placed in an iced cooler held at a temperature below 4^{o}C.

Samples collected concurrently with VOC samples to be tested for other analytical parameters shall be collected by extruding the soil out of the brass/stainless steel rings immediately adjacent to (above and below) the VOC sample interval. Soil chemistry samples not being analyzed for VOCs shall be placed in 8 or 16-ounce, laboratory cleaned, EPA-approved glass containers with Teflon® lined lids. This shall be done using clean stainless steel sampling tools. If soil from several brass/stainless steel rings must be composited to provide sufficient sample volume for a particular analysis, the sample shall be composited and homogenized in a stainless steel bowl using a stainless steel trowel or scoop. The sample shall then be transferred into the appropriate sample container, sealed, labeled, and place in an iced cooler held at a temperature below 4^{o}C.

The EnCore™ sampling procedure is as follows:

1) Remove sampler from the package and attach T-handle to the sampler body,

2) Quickly push the sampler into the soil until the sampler (coring body) is completely full (observe O-ring in viewing window),

3) Remove the sampler from the soil and wipe excess soil from the coring body exterior. A disposable laboratory-grade wipe should be used to clean the sampler,

4) Push the cap on with a twisting motion to firmly attach the cap. Push and twist over the bottom until the locking arms seat over the ridge on the sampler body,

5) Completely fill out the circular label (from the EnCore™ sampler bag) and attach it to the sampler, and

6) Return the sample-filled sampler to a self-sealing bag. Seal the bag and store the samples immediately on ice.

6.1.2.2 Sampling by Hand Auger

Hand augering is used to collect soil samples from depths up to 10 feet bgs, although the technique can sometimes be used to a depth as great as 30 feet bgs. VOCs may be sampled from the hand auger borehole using a manually driven sampling device (e.g., a JMC Environmental Subsurface Probe) once the hand auger has reached a predetermined depth.

6.1.2.3 Direct Push Sampling

Direct push sampling involves advancing a sampling probe by direct hydraulic pressure or by using a slide or rotary hammer. Samples may be collected continuously or at specific depths. The samples are collected in brass/stainless steel sleeves. The sleeve shall be capped with Teflon® tape and end caps. The ends of the capped sleeve shall then also be wrapped with Teflon® tape. Care shall be taken not to touch the ends of the sleeves prior to capping. Custody seals shall be placed across the capped ends of the sleeve. Once the container has been filled, the appropriate information shall be recorded in the field logbook.

6.1.3 Surface Soil Sampling

Surface soil samples shall be collected from the land surface to six inches below the surface. The sample shall be homogenized and quartered before being containerized. If chemicals that are highly adsorbed to clay surfaces were released at the site, an additional sample shall be collected from the surface to the 1-inch depth.

Stainless steel scoops or trowels, glass jars with Teflon® lids or equivalent equipment compatible with the chemical analyses proposed shall be used to collect and store samples. Exclude above ground plant parts and debris from the sample.

In addition to records outlined in Section 8.0, record unusual surface conditions that may affect the chemical analyses, such as the following: (1) asphalt chunks that may have been shattered by mowers, thus spreading small fragments of asphalt over the sampling area, (2) distance to roadways, aircraft runways, or taxiways, (3) obvious, deposition of contaminated or clean soil at the site, (4) evidence of dumping or spillage of chemicals, (5) soil discoloration, and/or (6) unusual condition of growing plants, etc.

6.1.4 Surface-Water Sampling

Collect samples so as not to cause cross-contamination. If collecting both water and sediment samples at a specific location, always obtain the water sample first. Measure and record pH, temperature, specific conductance, and dissolved oxygen (when required) at each surface water sampling point. Permanently mark the location where surface water or sediment samples are collected (e.g., flagged stake in stream bank). Record the location on a project map for each specific site or zone.

The sample collection sequence is as follows: (1) if sampling both water and sediment or just sediment, start at the most downstream point and proceed upstream, (2) if sampling water only and the sample can be taken without disturbing the river or stream bottom, obtain any background samples first, then the farthest downstream sample, and then move upstream toward the source or discharge point, (3) if sampling water only and the stream or river bottom must be disturbed, start at the most downstream point and proceed upstream,

Samples shall be taken from the active portion of the stream on the side nearest the source of contamination or suspected plume. Water samples are collected using a Van Dorn Sampler or Kemmerer Sampler when grab samples are required, or using an autosampler (discrete or composite samples) with the inlet line located at the desired sampling depth. If approved by AFCEE, surface-water samples may be collected by direct filling of sample bottles.
Samples from multiple locations are combined in a decontaminated bucket (nonvolatile samples only) and aliquots are taken for composite samples.

Surface-water samples may also be obtained using a continuous automatic sampler. With a continuous sampler, an intake probe is secured at the sampling point and the sampler is pre-programmed to collect either individual or composite samples at designated times throughout the day.

The following records shall be maintained in addition to those in Section 8.0: (1) the width, depth, and flow rate of streams, (2) surface-water conditions (e.g., floating oil or debris, gassing), (3) the location of any discharge pipes, sewers, or tributaries, and (4) instrument calibration.

6.1.5 Sediment Sampling

Sediment samples are collected from ponds, surface impoundments, and streambeds (both wet and dry). Sediment samples shall be collected using scoops or corers of appropriate material that are compatible with the contaminants of concern. Dry sediment samples may be collected by surface scraping, hand augering, or core sampling using a core sampler with stainless-steel sleeves. Methods for dry sediment sampling are the same as that for soil. Sediment samples may be collected near discharge points in areas where sediment has accumulated inside an edge of a bend, an area where a stream suddenly widens, and similar locations where sediment accumulates. The order of sample collection shall be the same as that described for surface-water samples.

6.1.6 Soil Gas Sampling

Soil gas may be sampled using commercially available soil gas sampling probes, a gas tight syringe or bulb, a SUMMA® canister, sorbent tubes or a Tedlar® bag.

When soil gas samples are collected using commercially available soil gas sampling probes, the probes are connected to a steel drive shaft used to push the probe to the desired sampling depth. The sampling container shall be a glass or metal bulb equipped with an entrance and exit spigot. The Tygon® tubing from the sampling probe shall be attached to the entrance spigot, and a second length of tubing shall run from the exit spigot of the bulb to a portable vacuum pump.

At each sample location, the sampling probes shall be driven to a previously determined depth of between 5 to 10 feet below ground surface.

When the probe is at the desired depth, the steel drive shaft shall be pulled back slightly, exposing the gas intakes on the sample probe. The vacuum pump shall then be switched on, drawing the gas contained in the interstitial spaces of the soil through the probe, tubing, and sample container. When 2 liters of gas have been drawn, the Tygon® tubing shall be clamped shut on the downstream side of the bulb (toward the pump) and then the upstream side of the bulb. The vacuum pump shall then be switched off. The volume of 2 liters shall ensure that the gas in the glass bulb originated from the soil interstitial space, rather than the tubing, so long as a reasonably short tubing length is used. Following sample collection, the sample container shall be labeled and the sample number recorded in the field log book along with the following information: soil gas sample or probe depth, apparent moisture content (dry, moist, saturated) of the sampled zone, if available, soil gas purge rate, sampling duration, sampling system leak rate, and pump vacuum, description of sample containers, location of sample analysis, location and grid layout of sampling stations.

Gas tight syringe or bulb samples are collected for on-site laboratory analyses. To collect a syringe sample, a fitting with a Teflon® septum shall be installed in the sampling line ahead of the purge pump. After purging the required volume, samples are collected. Bulb samples are collected using a manifold configuration.

SUMMA® Canister samples are collected for off-site laboratory analyses. A fitting for attaching the canister shall be installed in the sampling line ahead of the purge pump. Prior to sampling, the initial canister vacuum is measured, the canister is attached to the sample line, and the probe, etc. is purged. The canister sample is then collected.

Sorbent tubes may be used to collect samples for real-time field analysis (i.e., colorimetric tubes such as Draeger tubes) or for off-site laboratory analyses. The well or probe is purged, the sorbent tube is installed in the sampling line, and the required volume of soil gas is drawn through the tube. Colorimetric tubes are read directly, while sorbent tubes are capped and stored on ice (dry ice may be required) until being shipped to the laboratory.

Tedlar® bag samples can be collected for field analysis using real-time instruments or for off-site laboratory analysis. An oilless diaphragm pump is attached to the sampling line and a Tedlar® bag is attached to the pump exhaust. Samples shall be kept out of direct light and analyzed within 24 hours of collection to minimize the potential for loss, reaction, or degradation of VOCs.

In addition to the information listed in Section 8.0, the following information shall be recorded. If only qualitative data are required, only items 1 and 6 are needed: (1) soil gas sample or probe depth, (2) apparent moisture content (dry, moist, saturated) of the sampled zone, (3) soil gas purge rate, sampling duration, sampling system leak rate, and pump vacuum, (4) description of sample containers (if any), (5) location of sample analysis, (6) location and grid layout of sampling stations, (7) instrument calibration.

6.1.7 Indoor Air Sampling

This section describes a procedure for sampling and analysis of VOCs in indoor air. The method is based on collection of whole air samples in SUMMA inert stainless steel canisters.

The pressurized sampling module uses an initially evacuated canister and a pump ventilated sample line during sample collection. An additional pump is required to provide positive pressure to the sample canister. A sample of indoor air, collected near an exterior wall of the lowest level of a structure, is drawn through a sampling train composed of components that regulate the rate and duration of sampling into a pre-evacuated SUMMA passivated canister. After the air sample is collected, the canister valve is closed, an identification tag is attached to the canister, and the canister is transported to the laboratory for analysis.

6.2 SAMPLE HANDLING

The prime contractor shall identify types of sample containers, sample volumes, methods of preservation, sample identification, sample holding times, sample packaging, and shipping method.

6.2.1 Sample Containers

Sample containers are purchased precleaned and treated according to EPA specifications for the methods. Sampling containers that are reused are decontaminated between uses by the EPA-recommended procedures (i.e., EPA 540/R-93/051). Containers are stored in clean areas to prevent exposure to fuels, solvents, and other contaminants. Amber glass bottles are used routinely where glass containers are specified in the sampling protocol.

6.2.2 Sample Volumes, Container Types, and Preservation Requirements

Sample volumes, container types, and preservation requirements for the analytical methods performed on AFCEE samples are listed in Table 6.2.2-1.

Sample holding time tracking begins with the collection of samples and continues until the analysis is complete. Holding times for methods required routinely for AFCEE work are specified in Table 6.2.2-1. **Samples not preserved or analyzed in accordance with these requirements shall be resampled and analyzed, at no additional cost to AFCEE.**

The prime contractor shall provide detailed descriptions of the required sample volumes, container types, and preservation requirements for analytical methods proposed for project work not listed in Table 6.2.2-1.

Table 6.2.2-1. Requirements for Containers, Preservation Techniques, Sample Volumes, and Holding Times

Name	Analytical Methods	Container[a]	Preservation[b,c]	Minimum Sample Volume or Weight	Maximum Holding Time
Alkalinity	E310.1	P, G	4°C	50 mL	14 days
Common anions	SW9056	P, G	None required	50 mL	28 days for Br^-, F^-, Cl^-, and SO_4^{-2}; 48 hours for NO_3^-, NO_2^- and PO_4^{-3}
Cyanide, total and amenable to chlorination	SW9010A SW9012	P, G, T	4°C; NaOH to pH > 12, 0.6 g ascorbic acid	500 mL or 4 ounces	14 days (water and soil)
Filterable residue	E160.1	P, G	4°C	100 mL	7 days
Nonfilterable residue	E160.2	P, G	4°C	100 mL	7 days
Hydrogen ion (pH) (W, S)	SW9040/ SW9045	P, G	None required	N/A	Analyze immediately
Nitrogen, nitrate+nitrite	E353.1	P, G	4°C, H_2SO_4 to pH < 2	500 mL	28 days
Conductance	SW9050	P, G	None required	N/A	Analyze immediately
Temperature	E170.1	P, G	None required	N/A	Analyze immediately
Dissolved oxygen	E360.1	G	None required	500 mL	Analyze immediately
Turbidity	E180.1	P, G	4°C	N/A	48 hours
Settleable Solids	E160.5	P,G	None required	N/A	Analyze immediately
Total organic carbon	SW9060	P, G, T	4°C, HCl or H_2SO_4 to pH < 2	500 mL or 4 ounces	28 days (water and soil)
Chromium (VI)	SW7196A	P, G, T	4°C	500 mL or 8 ounces	24 hours (water and soil)[d]
Mercury	SW7470 SW7471	P, G, T	HNO_3 to pH < 2, 4°C	500 mL or 8 ounces	28 days (water and soil)
Metals (except chromium (VI) and mercury)	SW6010A SW6020 and SW-846 AA methods	P, G, T	HNO_3 to pH < 2, 4°C	500 mL or 8 ounces	180 days (water and soil)

a. Polyethylene (P); glass (G); brass sleeves in the sample barrel, sometimes called California brass (T).
b. No pH adjustment for soil.
c. Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.
d. The maximum recommended holding time for completion of extraction into water is 48 hours. The extract shall be analyzed within 24 hours of completion of extraction

Table 6.2.2-1. Continued

Name	Analytical Methods	Container[a]	Preservation[b,c]	Minimum Sample Volume or Weight	Maximum Holding Time
Total petroleum hydrocarbons (TPH)-volatile	SW8015 (modified)	G, Teflon®-lined septum, T	4°C, HCl to pH < 2	2 x 40 mL or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid
Total petroleum hydrocarbons (TPH)-extractable	SW8015 (modified)	G, amber, T	4°C	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Volatile aromatics	SW8020A	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	2 x 40 mL or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid
Halogenated volatiles	SW8021A	G, Teflon®-lined septum, T	4°C, HCl to pH < 2, 0.008% $Na_2S_2O_3$	2 x 40 mL or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid
Nitrosamines	SW8070	G, Teflon®-lined cap, T	4°C	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Chlorinated herbicides	SW8150B SW8151	G, Teflon®-lined cap, T	4°C, pH 5–9	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)

a. Polyethylene (P); glass (G); brass sleeves in the sample barrel, sometimes called California brass (T).
b. No pH adjustment for soil.
c. Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.

Table 6.2.2-1. Continued

Name	Analytical Methods	Container[a]	Preservation[b,c]	Minimum Sample Volume or Weight	Maximum Holding Time
Organochlorine pesticides and polychlorinated biphenyls (PCBs)	SW8080A, SW8081,	G, Teflon®-lined cap, T	4°C, pH 5–9	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organophosphorus pesticides/ compounds	SW8140 SW8141A	G, Teflon®-lined cap, T	4°C, pH 5–9	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Semivolatile organics	SW8270B	G, Teflon®-lined cap, T	4°C, 0.008% $Na_2S_2O_3$	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Volatile organics	SW8240B, SW8010B, SW8260A	G, Teflon®-lined septum, T	4°C, 0.008% $Na_2S_2O_3$ (HCl to pH < 2 for volatile aromatics by SW8240 and SW8260)[b]	2 x 40 mL or 4 ounces	14 days (water and soil); 7 days if unpreserved by acid
Polynuclear aromatic hydrocarbons (PAHs)	SW8310	G, Teflon®-lined cap, T	4°C, store in dark, 0.008% $Na_2S_2O_3$	1 liter or 8 ounces	7 days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)

a. Polyethylene (P); glass (G); brass sleeves in the sample barrel, sometimes called California brass (T).
b. No pH adjustment for soil.
c. Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.

Table 6.2.2-1. Concluded

Name	Analytical Methods	Container[a]	Preservation[b,c]	Minimum Sample Volume or Weight	Maximum Holding Time
Dioxins and furans	SW8280 SW8290	G, Teflon®-lined cap, T	4°C, 0.008% $Na_2S_2O_3$	1 liter or 8 ounces	30 days until extraction and 45 days after extraction (water and soil)
Ethylene dibromide (EDB)	SW8011	G, Teflon®-lined cap, T	4°C, 0.008% $Na_2S_2O_3$	2 x 40 mL	28 days (water)
Explosive residues	SW8330	P, G, T	Cool, 4°C	1 liter or 8 ounces	7 days to extraction (water); 14 days to extraction (soil); analyze-within 40 days after extraction
TCLP	SW1311	G, Teflon®-lined cap, T	Cool, 4°C	1 liter or 8 ounces	14 days to TCLP extraction and 14 days after extraction (volatiles); 14 days to TCLP extraction and 40 days after extraction (semivolatiles); 28 days to TCLP extraction and 28 days after extraction (mercury); 180 days to TCLP extraction and 180 days after extraction (metals)

a. Polyethylene (P); glass (G); brass sleeves in the sample barrel, sometimes called California brass (T).
b. No pH adjustment for soil.
c. Preservation with 0.008 percent $Na_2S_2O_3$ is only required when residual chlorine is present.

6.2.3 Sample Identification

The prime contractor shall describe procedures for unique sample identification and the relation to field identification (i.e., how sample numbers are assigned).

6.3 SAMPLE CUSTODY

Procedures to ensure the custody and integrity of the samples begin at the time of sampling and continue through transport, sample receipt, preparation, analysis and storage, data generation and reporting, and sample disposal. Records concerning the custody and condition of the samples are maintained in field and laboratory records.

The contractor shall maintain chain-of-custody records for all field and field QC samples. A sample is defined as being under a person's custody if any of the following conditions exist: (1) it is in their possession, (2) it is in their view, after being in their possession, (3) it was in their possession and they locked it up or, (4) it is in a designated secure area.

All sample containers shall be sealed in a manner that shall prevent or detect tampering if it occurs. In no case shall tape be used to seal sample containers. Samples shall not be packaged with activated carbon unless prior approval is obtained from the AFCEE.

The following minimum information concerning the sample shall be documented on the AFCEE chain of custody (COC) form (as illustrated in Section 8):

- Unique sample identification
- Date and time of sample collection
- Source of sample (including name, location, and sample type)
- Designation of matrix spike/matrix spike duplicate (MS/MSD)
- Preservative used
- Analyses required
- Name of collector(s)
- Pertinent field data (e.g., pH, temperature)
- Serial numbers of custody seals and transportation cases (if used)
- Custody transfer signatures and dates and times of sample transfer from the field to transporters and to the laboratory or laboratories
- Bill of lading or transporter tracking number (if applicable)

All samples shall be uniquely identified, labeled, and documented in the field at the time of collection IAW Section 6.2.3 of the FSP.

Samples collected in the field shall be transported to the laboratory or field-testing site as expeditiously as possible. When a 4°C requirement for preserving the sample is indicated, the samples shall be packed in ice or chemical refrigerant to keep them cool during collection and transportation. During transit, it is not always possible to rigorously control the temperature of the samples. As a general rule, storage at low temperature is the best way to preserve most samples. A temperature blank (a volatile organics compounds sampling vial filled with water) shall be included in every cooler and used to determine the internal temperature of the cooler upon receipt of the cooler at the laboratory.

6.4 FIELD QUALITY CONTROL SAMPLES

6.4.1 Ambient Blank

The ambient blank consists of ASTM Type II reagent grade water poured into a volatile organic compound (VOC) sample vial at the sampling site. It is handled like an environmental sample and transported to the laboratory for analysis. Ambient blanks are prepared only when VOC samples are taken and are analyzed only for VOC analytes.

Ambient blanks are used to assess the potential introduction of contaminants from ambient sources (e.g., active runways, engine test cells, gasoline motors in operation, etc.) to the samples during sample collection. Ambient blanks shall be collected downwind of possible VOC sources. The frequency of collection for ambient blanks is specified in Section 3.2.

6.4.2 Equipment Blank

An equipment blank is a sample of ASTM Type II reagent grade water poured into or over or pumped through the sampling device, collected in a sample container, and transported to the laboratory for analysis. Equipment blanks are used to assess the effectiveness of equipment decontamination procedures. The frequency of collection for equipment blanks is specified in Section 3.2. Equipment blanks shall be collected immediately after the equipment has been decontaminated. The blank shall be analyzed for all laboratory analyses requested for the environmental samples collected at the site.

6.4.3 Trip Blank

The trip blank consists of a VOC sample vial filled in the laboratory with ASTM Type II reagent grade water, transported to the sampling site, handled like an environmental sample and returned to the laboratory for analysis. Trip blanks are not opened in the field. Trip blanks are prepared only when VOC samples are taken and are analyzed only for VOC analytes. Trip blanks are used to assess the potential introduction of contaminants from sample containers or during the transportation and storage procedures. One trip blank shall accompany each cooler of samples sent to the laboratory for analysis of VOCs.

6.4.4 Field Duplicates

A field duplicate sample is a second sample collected at the same location as the original sample. Duplicate samples are collected simultaneously or in immediate succession, using identical recovery techniques, and treated in an identical manner during storage, transportation, and analysis. The sample containers are assigned an identification number in the field such that they cannot be identified (blind duplicate) as duplicate samples by laboratory personnel performing the analysis. Specific locations are designated for collection of field duplicate samples prior to the beginning of sample collection.

Duplicate sample results are used to assess precision of the sample collection process. Precision of soil samples to be analyzed for VOCs is assessed from collocated samples because the compositing process required to obtain uniform samples could result in loss of the compounds of interest. The frequency of collection for field duplicates is specified in Section 3.2.

6.4.5 Field Replicates

A field replicate sample, also called a split, is a single sample divided into two equal parts for analysis. The sample containers are assigned an identification number in the field such that they cannot be identified as replicate samples by laboratory personnel performing the analysis. Specific locations are designated for collection of field replicate samples prior to the beginning of sample collection. Replicate sample results are used to assess precision. The frequency of collection for field replicates is specified in Section 3.2.

6.5 Environmental Data Reporting: Significant Digits Reflect Quantification Uncertainty

Field measurements of common water-quality parameters (e.g., EC, DO), other screening analytical data, calculations of aquifer properties (e.g., hydraulic conductivity, transmissivity, groundwater velocity), and quantities of contaminated soil and water removed and/or treated possess measurable uncertainty or error ranges. When reporting these data, therefore, the number of significant figures employed should reflect the true accuracy and precision (reproducibility) of these measured and calculated values. As a general rule of thumb, field measurements of water quality parameters, quantities of contaminated media removed/remediated, screening analytical data and calculated aquifer properties rarely yield better than two-significant-figure accuracy and precision. Consequently, these field-measured parameters typically should be reported to two significant figures (e.g., DO, 2.1 mg/L; hydraulic conductivity, 120 ft/day; transmissivity, 1,100 ft^2/day; 130 tons of contaminated soil excavated) unless notably low uncertainty exists to justify reporting to three or more significant figures. Manufacturer's performance specifications that document high accuracy and precision for field meters may constitute an example of valid justification for reporting field values to three or more significant figures. Because pH and oxidation-reduction potential are logarithmic values, recommend reporting these parameters to three significant figures. In all cases, standard reporting practice should involve consistency in the number of significant figures used to report measured values.

Definitive analytical data also possess some degree of uncertainty in the final reported values. Only small amounts of definitive data probably possess the required accuracy and precision to be reported to more than three significant figures. The recommendations stated in this section of the MFSP do not set policy for determining the number of significant figures AFCEE laboratories should use in reporting their data. However, contractors and AFCEE staff should constantly recall that the analytical method/analysis is one of the last links in a very long chain of events that forms the foundation of environmental data. Contractors, consequently, are encouraged to use sound scientific judgment in choosing the appropriate number of significant figures and to be consistent in the number of significant figures used to report definitive analytical data in field sampling plans, work plans, site characterization and contamination reports and other IRP documents.

Use of scientifically defensible and consistent numbers of significant figures in reporting analytical and quantitative field data in IRP reports allows the readers and users of these data to properly evaluate measurement uncertainty. This proper evaluation of data accuracy and precision facilitates the scientifically valid interpretation, summarization and subsequent reporting of these data. Contractors are encouraged to comply with *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications* (ASTM Designation: E 29—93a (Reapproved 1999).

7.0 FIELD MEASUREMENTS

7.1 PARAMETERS

The prime contractor shall identify (1) all the parameters to be measured in the field and, (2) the equipment that will be used for the measurements.

7.2 EQUIPMENT CALIBRATION AND QUALITY CONTROL

The prime contractor shall describe (1) calibration procedures and frequency for the field tests, (2) the source of calibration materials, (3) the quality control materials and frequency for the field tests, (4) the quality control limits and acceptance criteria for the quality control materials, (5) the acceptance criteria for calibration procedures, (6) the corrective actions for out-of-control events for both calibration and quality control samples, (7) the actions required by field personnel in the event that control parameters exceed the acceptance criteria, and (8) the form used to document exceedence of criteria and subsequent corrective actions.

pH meters shall be calibrated daily. At least two buffer solutions that bracket the probable sample pH (e.g., 4.0 and 9.0) shall be used.

EC meters shall be calibrated daily. At least two solutions that bracket the expected sample EC shall be used.

Dissolved oxygen meters shall be calibrated daily. At least two solutions that bracket the potential sample DO concentrations should be used. One standard solution should contain 0.0 mg/L DO and a second solution should consist of temperature-compensated, air-saturated water. The electronic calibration shall be checked before each use.

Turbidity meters shall be calibrated at least daily using a standard solution within the expected range of sample turbidity.

7.3 EQUIPMENT MAINTENANCE AND DECONTAMINATION

The prime contractor shall describe the field equipment maintenance procedures and schedules. Also describe all the decontamination procedures used for field measurement devices, or reference Section 5.12.

All field measurement equipment shall be decontaminated according to the specifications in Section 5.12 prior to any measurement activities and shall be protected from contamination until ready for use.

7.4 FIELD MONITORING MEASUREMENTS

7.4.1 Ground-water Level Measurements

Water-level measurements shall be taken in all wells and piezometers to determine the elevation of the water table or piezometric surface at least once within a single 24-hour period. These measurements shall be taken after all wells and piezometers have been installed and developed and their water levels have recovered completely. Any conditions (e.g., barometric pressure) that may affect water levels shall be recorded in the field log. The field log shall also include the previous water level measurement for each well (to determine if current water level is reasonable).

Water-level measurements shall be taken with electric sounders, air lines, pressure transducers, or water-level recorders (e.g., Stevens recorder). Devices that may alter sample composition shall not be used. Pressure gauges, manometers, or equivalent devices shall be used for flowing wells to measure the elevation of the piezometric surface. All measuring equipment shall be decontaminated according to the specifications in Section 7.3 and 5.12. Ground-water level shall be measured to the nearest 0.01 foot. (Two or more sequential measurements shall be taken at each location until two measurements agree to within + or - 0.01 foot.)

Static water levels shall be measured each time a well is sampled, and before any equipment enters the well. If the casing cap is airtight, allow time prior to measurement for equilibration of pressures after the cap is removed. Repeat measurements until water level is stabilized.

7.4.2 Floating Hydrocarbon Measurements

The thickness of hydrocarbons floating in monitor wells shall be measured with an electronic interface probe. Hydrocarbon detection paste, or any other method that may affect water chemistry, shall not be used. When detected, the presence of floating hydrocarbons shall be confirmed by withdrawing a sample with a clear, bottom-fill Teflon® bailer.

7.4.3 Ground-water Discharge Measurements

Ground-water discharge measurements shall be obtained during monitor well purging and aquifer testing. Ground-water discharges may be measured with orifice meters, containers of known volume, in-line meters, flumes, or Weirs, following the guidelines specified in the *Water Measurement Manual*, Bureau of Reclamation, 1967. Measurement devices shall be calibrated using containers of known volume.

7.5 FIELD PERFORMANCE AND SYSTEM AUDITS

The prime contractor shall describe the type of field performance and system audits that will be performed. Audit frequencies and personnel will be identified. The officials who receive and act upon the audit reports shall be identified.

8.0 RECORD KEEPING

The prime contractor shall identify the records of field operations, sampling, and measurements that will be maintained by field personnel. Include the forms from the approved AFCEE forms to be used. Obtain approval from AFCEE and include any additional forms that will be used.

The contractor shall maintain field records sufficient to recreate all sampling and measurement activities and to meet all ERPIMS data loading requirements. The requirements listed in this section apply to all measuring and sampling activities. Requirements specific to individual activities are listed in the section that addresses each activity. The information shall be recorded with indelible ink in a permanently bound notebook with sequentially numbered pages. These records shall be archived in an easily accessible form and made available to the Air Force upon request.

The following information shall be recorded for all field activities: (1) location, (2) date and time, (3) identity of people performing activity, and (4) weather conditions. For field measurements: (1) the numerical value and units of each measurement, and (2) the identity of and calibration results for each field instrument, shall also be recorded.

The following additional information shall be recorded for all sampling activities: (1) sample type and sampling method, (2) the identity of each sample and depth(s), where applicable, from which it was collected, (3) the amount of each sample, (4) sample description (e.g., color, odor, clarity), (5) identification of sampling devices, and (6) identification of conditions that might affect the representativeness of a sample (e.g., refueling operations, damaged casing).

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APPENDIX A

Place any exception to or deviation from the requirements in AFCEE contract, corresponding SOW, the AFCEE QAPP and this model FSP in this appendix of the draft and final FSP. Identify the document, chapter, subtitle, paragraph, page, and line proposed to be changed. Supply supporting justification for the change. Written authorization of the AFCEE contracting officer must be obtained and included in the final version of this appendix for any proposed exception to or deviation from these requirements. No project work shall be performed until the written authorization has been obtained.

Appendix B

Model FSP Forms

BORING LOG

Borehole ID: __________
Sheet _____ of ____

Location	Northing:				
	Easting:				

Project Name		Project Number	LTCCODE (ERPIMS)	Site ID	LPRCODE (ERPIMS)
Drilling Company		Driller	Ground Elevation	Total Drilled Depth	
Drilling Equipment	Drilling Method	Borehole Diameter	Date/Time Drilling Started	Date/Time Total Depth Reached	
Type of Sampling Device			Water Level (bgs) First Final		
Sample Hammer Type Driving Wt. Drop			Hydrogeologist	Checked by/Date	
Location Description (include sketch in field logbook)					

Depth	Interval	Recovery	Blow Counts	Description (Include lithology, grain size, sorting, angularity, Munsell color name & notation, minerology, bedding, plasticity, density, consistency, etc., as applicable)	USCS Symbol	Lithology	Water Content	Remarks (Include all sample types & depth, odor, organic vapor measurements, etc.)

WELL DEVELOPMENT RECORD

WELL/PIEZOMETER ID _ _______
SHEET _______ of ________

PROJECT NAME: ___________________ PROJECT NO. : _______________________________ DATE: ________________________

LOCATION: ________________________ DATE INSTALLED: ____

TOTAL DEPTH (FTOC) ______________ CASING DIAMETER ____

METHODS OF DEVELOPMENT

☐ Swabbing ☐ Bailing ☐ Pumping ☐ Describe ____

Equipment decomtaminated prior to development ☐ Yes ☐ NO

Describe____

EQUIPMENT NUMBERS:

pH Meter _________________ EC Meter __________________ Turbidity Meter ________________ Thermometer _________________

CASING VOLUME INFORMATION:

Casing ID (inch)	1.0	1.5	2.0	2.2	3.0	4.0	4.3	5.0	6.0	7.0	8.0
Unit Casing Volume (A) (gal/ft)	0.04	0.09	0.16	0.2	0.37	0.65	0.75	1.0	1.5	2.0	2.6

PURGING INFORMATION:

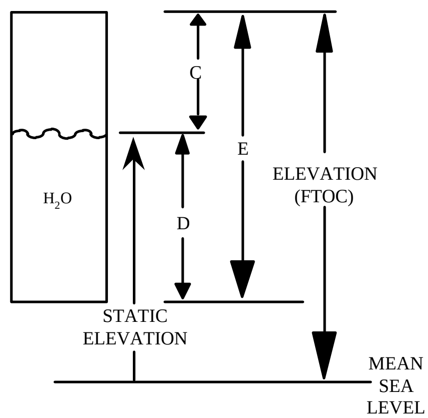
Measured Well Depth (B) ___________________________ft.

Measured Water Level Depth (C) _____________________ft.

Length of Static Water Colume (D) ________ - ________ = __________ ft.
(B) (C)

Casing Water Volume (E) + ________ x _________ = __________ gal
(A) (D)

Total Purge Volume = __________ (gal)



Date	Time	Water Level (FTOC)	Volume Removed (gal)	pH	EC	Temperature F or C	Turbidity/ Sand (ppm)	Comments

AQUIFER TEST DATA FORM

AQUIFER TEST DATA

LOCATION ________________________________ SLUG VOLUME (FT^3) ___________________

LOCATION I.D. ____________________________ LOGGER CODE ________________________

LOGDATE ________________________________ ACCEPTANCE CODE ___________________

TEST METHOD: ____

COMMENTS: ____

____

____

ELAPSED TIME (MIN)	DEPTH-TO-WATER (FT)	ELAPSED TIME (MIN)	DEPTH-TO-WATER (FT)
0.00			

ACCEPTANCE CODES: A - ACCEPTABLE R - RECONNAISSANCE U - UNACCEPTABLE N - NOT DETERMINED

FORM COMPLETED BY / DATE

TECHNICAL REVIEWER / DATE

WASTE INVENTORY TRACKING FORM

LOCATION : ____

PROJECT NAME:____

ACTIVITIES: ____

Date Waste Generated	Activity Generating Waste (borehole # / well #)	Description of Waste	Field Evidence of Contamination	Estimated Volume	Type of Container (storage ID#)	Location of Container	Waste Characterization	Comments

Note: Describe whether soil or water samples have been collected for waste characterization, include date, if known.

Signature: ____

SLUG TEST DATA FORM

SLUG TEST DATA

LOCATION ________________________________ SLUG VOLUME (FT^3) ___________________

LOCATION I.D. ____________________________ LOGGER CODE ________________________

LOGDATE ________________________________ ACCEPTANCE CODE __________________

TEST METHOD: [ ] SLUG INJECTION OR [ ] SLUG WITHDRAWAL

COMMENTS: ____

____

____

ELAPSED TIME (MIN)	DEPTH-TO-WATER (FT)	ELAPSED TIME (MIN)	DEPTH-TO-WATER (FT)
0.00			

ACCEPTANCE CODES: A - ACCEPTABLE R - RECONNAISSANCE U - UNACCEPTABLE N - NOT DETERMINED

______________________________ ______________________________

FORM COMPLETED BY / DATE TECHNICAL REVIEWER / DATE

MONITOR WELL STATIC WATER LEVEL FORM

PROJECT NAME: ___________________________ DATE: __________________

WATER LEVEL INDICATOR ID # ____________ FIELD BOOK # ___________

LOCATION: _______________________________ PAGE # _________________

Monitor Well Number	Total Well Depth	Well Screen Length	Measuring Point Elev.	Time	Depth to Static Water Level	Sounding	Explosimeter Reading (above background)	PID Reading (above background)

Note: Total well depth to be measured at time of gauging.

Comments: ____

____

____

Sampler ___________________________________ Observer __________________________________

MONITOR WELL PURGING FORM

PROJECT : ______________________________ DATE: ________________

LOCATION: ______________________________ EXPLOSIMETER BOREHOLE READING _________

WELL ID: ________________________________ PURGE VOLUME
(3 WELLBORE VOLUMES): ________________ (gal)

WELL DEPTH: ____________________________

Time	Depth to Water (ft)	Flow Meter Reading	Volume Purged (gal)	Temp. (^oC)	pH	Electrical Conductivity (mmho)	Turbidity N.T.U	Comments

Note: Condition of the well: ____

pH - Calibrate at start and before last reading.

Sampler _________________________________ Observer _________________________________

FIELD SAMPLING REPORT

LOCATION: ________________________ PROJECT : ___________________________

SITE: ______________________________

SAMPLE INFORMATION

MATRIX ___________________________ SAMPLE ID: __________________________

SAMPLING METHOD ________________ DUP./REP. OF : ________________________

BEGINNING DEPTH _________________ MATRIX SPIKE/MATRIX SPIKE DUPLICATE
YES ( ) NO ( )

END DEPTH ________________________

GRAB ( ) COMPOSITE ( ) DATE: _____________ TIME: ___________

CONTAINER SIZE/TYPE	#	PRESERVATIVE/ PREPARATION	EXTRACTION METHOD	ANALYTICAL METHOD	ANALYSIS

NOTABLE OBSERVATIONS

PID READINGS	SAMPLE CHARACTERISTICS	MISCELLANEOUS
1st	COLOR:	
2nd	ODOR:	
	OTHER:	

pH _______ Temperature _________ Dissolved oxygen ___________ Specific Conductivity__________

GENERAL INFORMATION

WEATHER: SUN/CLEAR _____ OVERCAST/RAIN _____ WIND DRIECTION ________ AMBIENT TEMP _______

SHIPMENT VIA: FED-X _____ HAND DELIVER ______ COURIER ________ OTHER ________

SHIPPED TO: ____

COMMENTS: ____

SAMPLER: _____________________________ OBSERVER: _________________________________

MATRIX TYPE CODES

DC=DRILL CUTTINGS
WG=GROUND WATER
LH=HAZARDOUS LIQUID WASTE
SH=HAZARDOUS SOLID WASTE
SE=SEDIMENT
SL=SLUDGE
SO=SOIL
GS=SOIL GAS
WS=SURFACE WATER
SW=SWAP\WIPE

SAMPLING METHOD CODES

B=BAILER
BR=BRASS RING
CS=COMPOSITE SAMPLE
C=CONTINUOUS FLIGHT AUGER
DT=DRIVEN TUBE
W=SWAB\WIPE
G=GRAB
HA=HAND AUGER
H=HOLLOW STEM AUGER
HP=HYDRO PUNCH
SS=SPLIT SPOON
SP=SUBMERSIBLE PUMP

WELL CONSTRUCTION DETAILS AND ABANDONMENT FORM

FIELD REPRESENTATIVE: ________________________

DRILLING CONTRACTOR: ________________________

DRILLING TECHNIQUE: __________________________
AUGER SIZE AND TYPE: __________________________

BOREHOLE IDENTIFICATION: _____________________
BOREHOLE DIAMETER: ___________________________
WELL IDENTIFICATION: __________________________

WELL CONSTRUCTION START DATE: ______________
WELL CONSTRUCTION COMPLETE DATE: __________

SCREEN MATERIAL: ______________________________
SCREEN DIAMETER: ______________________________
SCREENED INTERVAL(S) (FT): _____________________

CASING MATERIAL: ______________________________
CASING DIAMETER: ______________________________

TYPE OF FILTER PACK: ____________________________
GRADATION: _____________________________________
AMOUNT OF FILTER PACK USED: __________________

TYPE OF BENTONITE: _____________________________
AMOUNT BENTONITE USED: ________________________

TYPE OF CEMENT: ________________________________
AMOUNT CEMENT USED: ___________________________
GROUT MATERIALS USED: _________________________

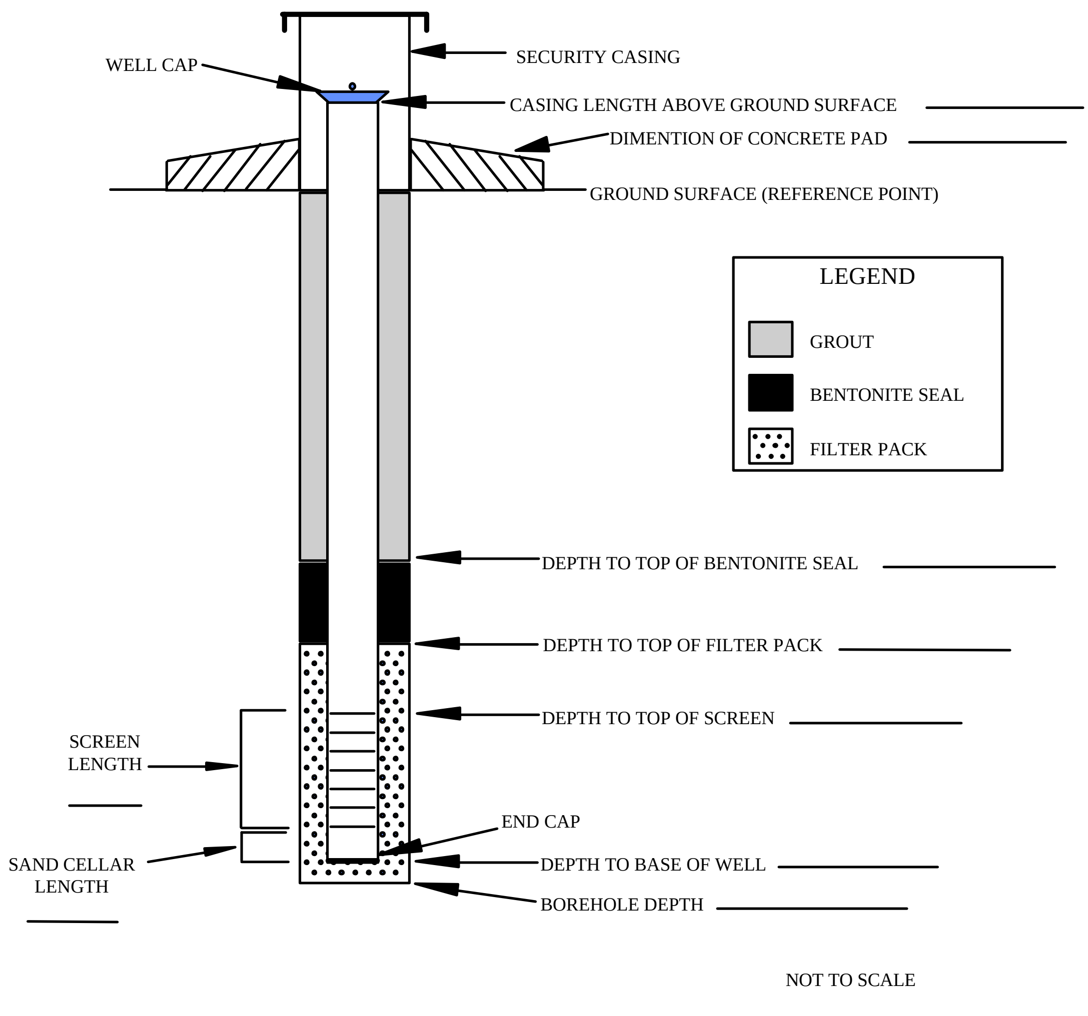
DIMENSIONS OF SECURITY CASING: _______________

TYPE OF WELL CAP: _______________________________
TYPE OF END CAP: ________________________________

LOCATION: Northing: ______________________________
Easting: ______________________________

COMMENTS:

SPECIAL CONDITIONS
(describe and draw)



NOT TO SCALE

INSTALLED BY: ___________________________ INSTALLATION OBSERVED BY: ____________________________

DISCREPANCIES: ____

WELL CONSTRUCTION DETAILS AND ABANDONMENT FORM

FIELD REPRESENTATIVE: ________________________

DRILLING CONTRACTOR: ________________________

DRILLING TECHNIQUE: __________________________
AUGER SIZE AND TYPE: __________________________

BOREHOLE IDENTIFICATION: _____________________
BOREHOLE DIAMETER: ___________________________
WELL IDENTIFICATION: __________________________

WELL CONSTRUCTION START DATE: ______________
WELL CONSTRUCTION COMPLETE DATE: __________

SCREEN MATERIAL: _____________________________
SCREEN DIAMETER: _____________________________
SCREENED INTERVAL(S) (FT): ____________________

CASING MATERIAL: _____________________________
CASING DIAMETER: _____________________________

TYPE OF FILTER PACK: ____________________________
GRADATION: _____________________________________
AMOUNT OF FILTER PACK USED: __________________

TYPE OF BENTONITE: _____________________________
AMOUNT BENTONITE USED: ______________________

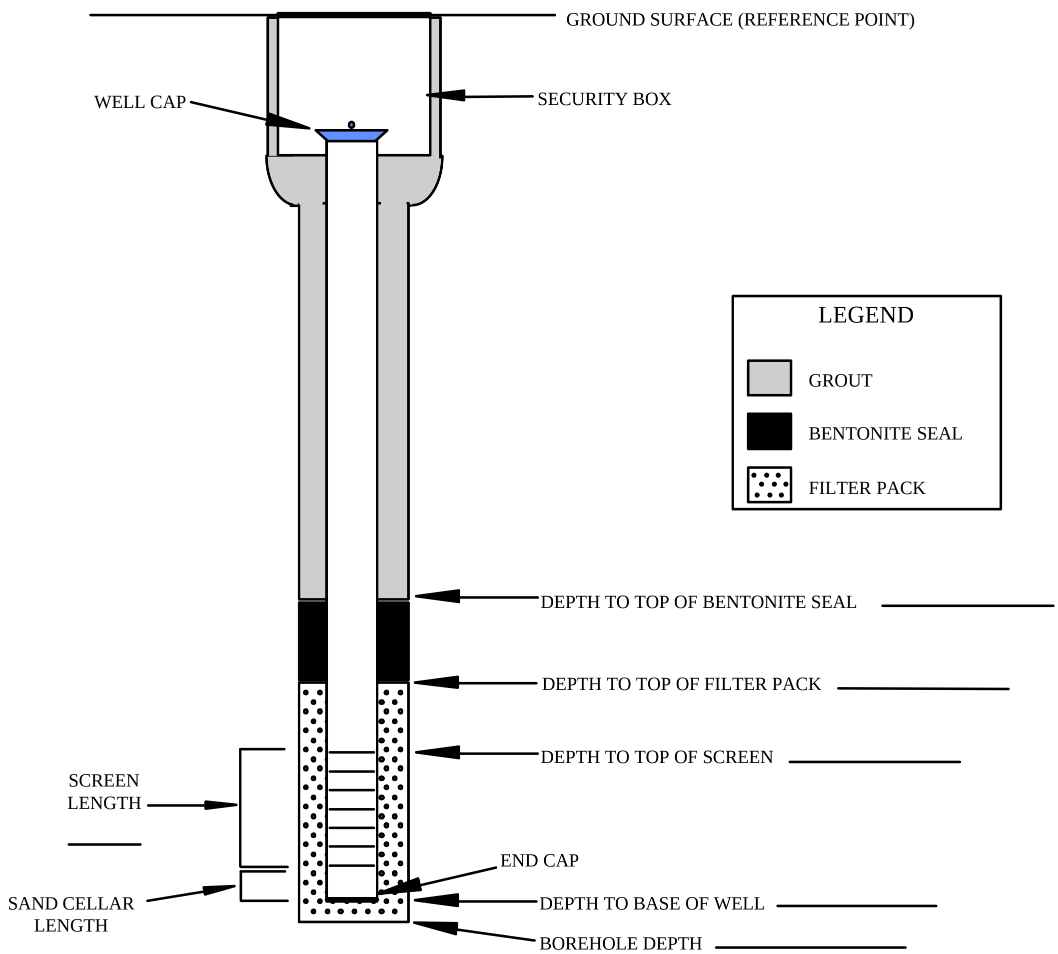
TYPE OF CEMENT: _________________________________
AMOUNT CEMENT USED: _________________________
GROUT MATERIALS USED: _______________________

DIMENSIONS OF SECURITY BOX: __________________

TYPE OF WELL CAP: ______________________________
TYPE OF END CAP: _______________________________

LOCATION: Northing: ______________________________
Easting: _______________________________
COMMENTS:

SPECIAL CONDITIONS
(describe and draw)



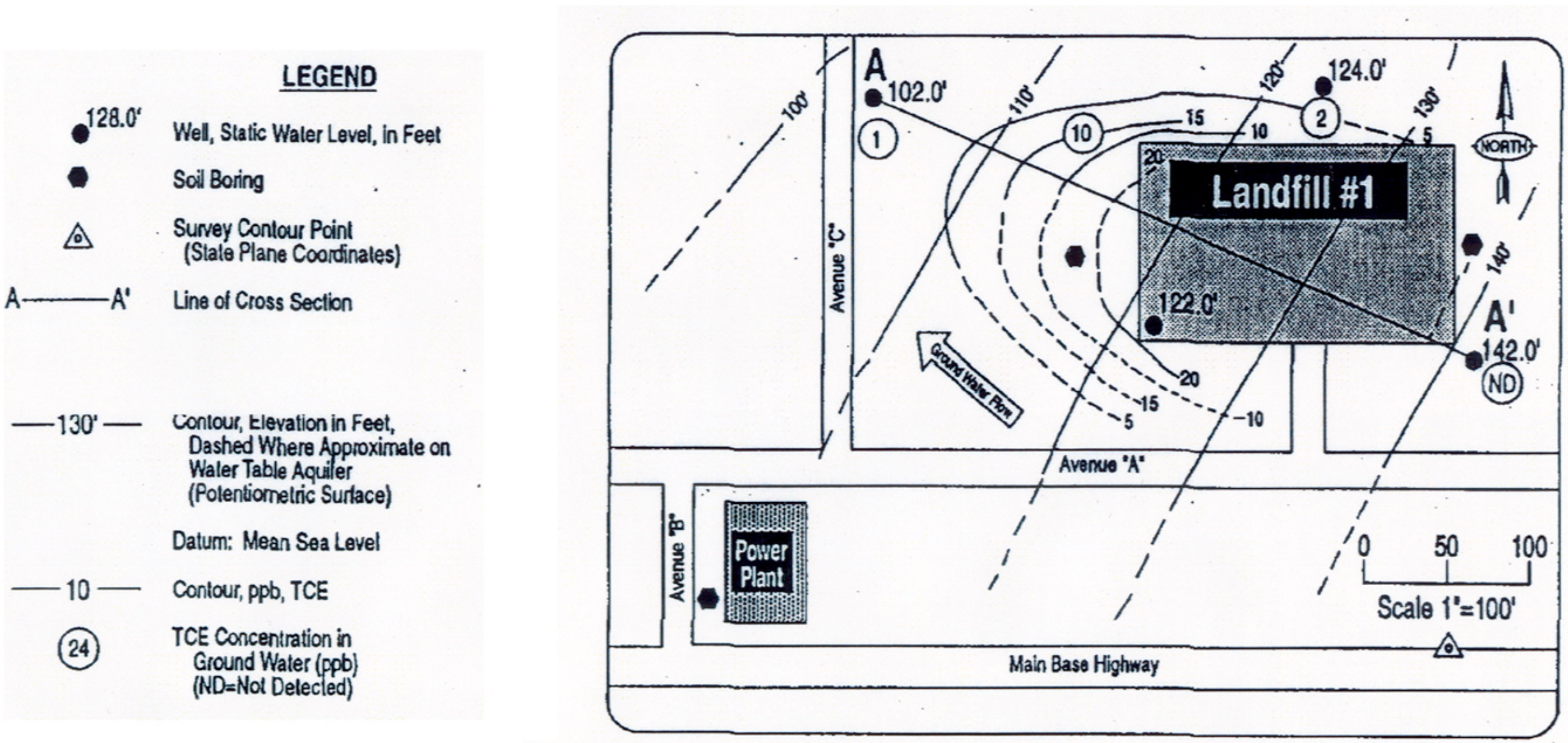
NOT TO SCALE

INSTALLED BY: ____________________________ INSTALLATION OBSERVED BY: ____________________________

DISCREPANCIES: ____

APPENDIX C

FIGURES 5-2 AND 5-3



Note to drafting: Symbols may be used to indicate single samples or suites of samples. Cultural information or topographic base should be screened 50%. Contour data for individual contaminants, separate aquifers, iterative phrases of sampling, etc, may be shown on separate maps, on overlays, or in different colors, as appropriate.

Site Characterization Plan View Figure, Site 2, Air Force Base, County, State
TCE Concentrations and Groundwater Contours (Month, Year)

Data Compiled From Stage 1 PA Report Prepared by Consulting Firm, Inc.

(In this example, additional investigation is necessary to characterize extent of TCE contamination.)

Figure 5-2. Hydrogeologic Conceptual Site Model Map

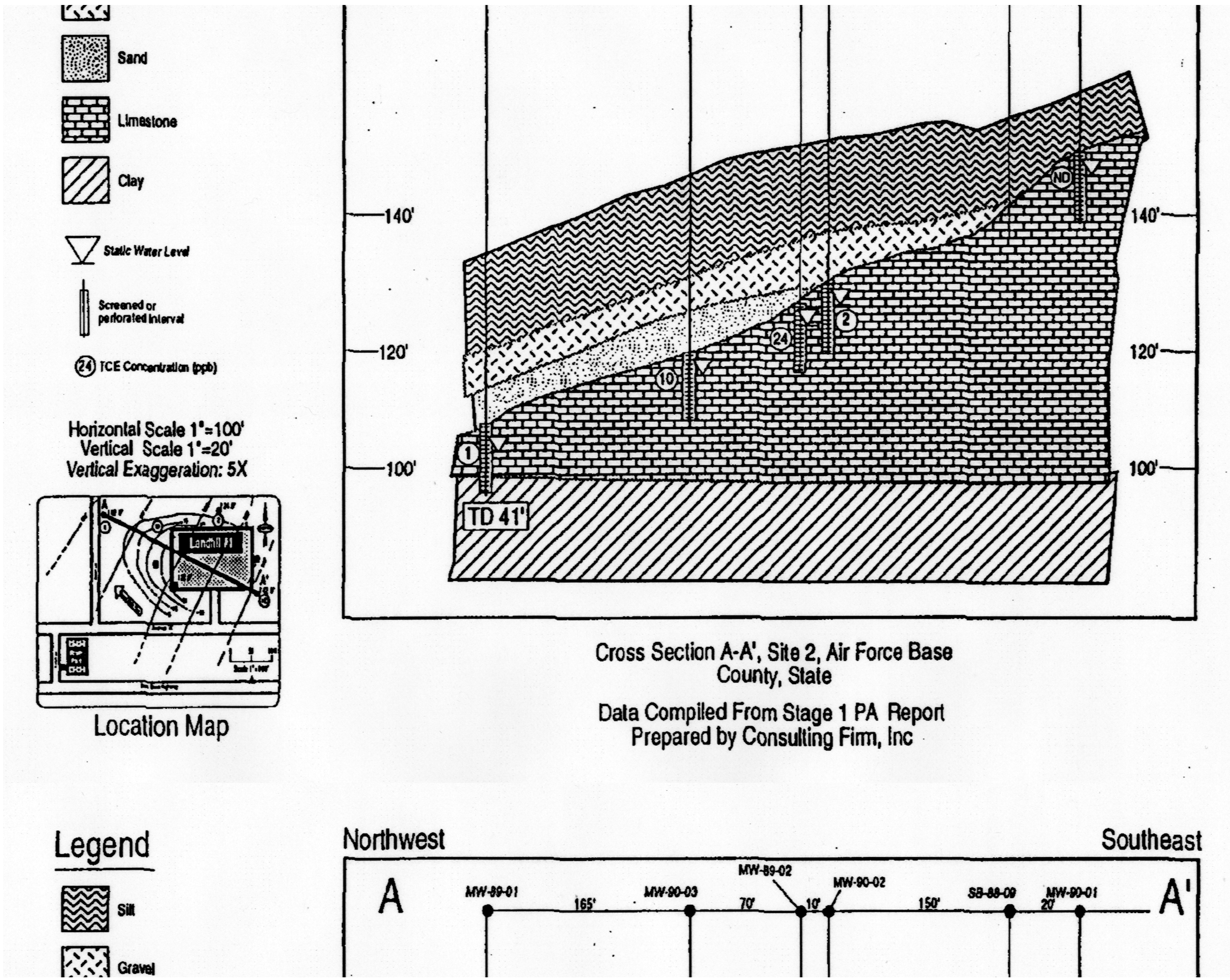


Figure 5-3. Hydrogeologic Conceptual Site Model Cross Section